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The Relative Value of Milling and Planing.*

By WALTER DUCKITT.

THE relative merits of milling and planing processes is a subject which has received the attention of some of our most capable engineers and machine tool builders during the past few years, and much has been said in relation thereto. Speaking broadly on the question, however, and without being interested in the sale of either type of machine, it must be admitted that the field of operation of the planer is comparatively small compared with that of the miller, the latter machine having developed during recent years to such an extent as to bring it, by virtue of its cutting qualities and general adaptability, into the front rank of machine tools, and to render it an indispensable acquisition to the shops. It has by no means, however, displaced its older rival the planing machine, which has also to be considered in its redesigned and appropriately named "high speed" type. With a cutting speed of 50 ft. per minute and a return of anything up to 200 ft. per minute, these machines are the result of the advent of "high speed" steel, which, as is hardly necessary to point out, retains its cutting edges at a speed which was unheard of a few years ago.

One of the chief and most advantageous features of the planing machine is the comparative cheapness of its cutting tools and general equipment, as compared with those required for its more modern competitor, the miller. The former, when belted up, can generally be set to work at once, as any tool smith can easily forge the general run of cutting tools that are required, whereas in the case of the miller a large equipment of cutters and fixtures are required, sometimes amounting in value to hundreds of pounds, according to the nature of the work it is intended to operate on, and the design and type of the machine the equipment is intended for.

Whilst dealing with the cost of the cutter and general equipment of the milling machine upon which the success of the machine entirely depends, a

* £10 Prize article.

regrettable fact may here be mentioned, viz., that some of the firms begrudge every penny that is spent upon accessories, the machine being installed in the shop with a few plain cutters and arbors usually supplied with it, and it is expected of the operator to tackle any and every job which comes along, and to do it at a fraction of the cost it has hitherto been completed at. This is a mistake which most works managers now fortunately realise, and needless to say, where a good stock of cutters and a thorough equipment is not provided, a greatly reduced output is the result, the machine sometimes being blamed as not coming up to expectations.

The milling machine in some respects is at a disadvantage as compared with the planer, namely, that whereas the former requires a good tool room to keep its equipment in thorough order, a tool smith and a simple grinder suffice for the latter. Even with this to be said in favour of the planer, however, it must not be taken that it scores as heavily as at first appears in the matter of cost of equipment, as most of the leading brands of high speed cutting steel now on the market are very expensive, and in a full set of tools for a planer therefore, there is a large amount of capital sunk in the weight of steel alone, to say nothing of the labour. On the other hand, the experienced works manager will admit that capital sunk in equipment for the miller is equivalent to buying "the goose that lays the golden eggs," as a milling cutter when properly hardened and ground will sometimes last as long as fifty or even a hundred planer tools, so that their cost of upkeep is comparatively small. Further, they do not require a tool smith to manipulate them, and although he may be a necessity, he is not the lowest paid man in the shop, and, if we believe him, he has generally more work than he can cope with, which is demonstrated by the pile of mutilated tools more often than not to be found on his hearth.

Milling machines which enter the field of competition with the planer may be classified under vertical and horizontal types, subdivided again into classes, designed either for the general run of work, or for special operations. Of the horizontal spindle type there is the small hand feed class, which can scarcely be said to come into actual competition with the planer, except for milling keyways into shafts, spindles, and such like work, which, if of any length, was formerly done entirely on planers. For keyway cutting the milling machine may fairly claim to have scored heavily, and of late years has taken this class of work entirely off the planers, as with the latter machine a highly-skilled man is required to cut the keyway to its proper dimensions, whereas with a miller all that is required is a simple keyway cutter of the required width, and the only dimension the operator has to watch is the depth. A comparatively unskilled, and, therefore, much lower rated man can accomplish this.

Coming to the "Lincoln" type of miller which is chiefly used for manufacturing operations of the medium and light trades, such as automobiles, small arms, sewing machines and bicycles; indeed it is in a great measure due to this type of machine that these trades have developed to their present magnitude, enabling the various small operations to be performed by cheap labour by the aid of jigs and fixtures, coupled of course with good supervision. A very large variety of beautiful and interesting operations can be performed on the "Lincoln" miller for a mere fraction of the cost that would be involved were a planer used.

We then come to the upright plain miller with overhanging arm for support to the cutter arbor and adjustable knee or table support. These machines are now made up to fairly large dimensions, are very massive and powerful and are adaptable to a wide range of work to which the planer formerly claimed a monopoly, effecting, in the majority of cases where they are employed, a very considerable economy.

A very good example and typical

piece of work suitable for either the "Lincoln" or upright plain types is the forged steel cotter shown in Figs. 10, 11, and 12. Machined all over for the connecting rod ends of a large stationary "Corliss" engine, this is an extremely difficult and highly skilled piece of work to perform on the planer, due to so many curved surfaces and radius corners for forming the head. It formerly took nine hours to plane and then only resulted in a very imperfect job, necessitating several hours filing and fitting to finish it. A boy now completes in a miller in 4¼ hours, representing a clear saving in labour cost of over 250 per cent. The cotter first is gripped in a swivel jaw machine vice and milled on the flat faces with the two ganged cutters as shown in the end elevation in Fig. 12, the second operation being to mill the convex edge with a concave cutter of the proper radius as shown in Figs. 10 and 11. A similar cutter of larger radius is afterwards used to mill the top end round the bolt hole. The inside of the head is then milled to thickness with a straddle milling cutter, the remaining flat edge for the gib to fit against being done with an end milling cutter in a vertical spindle machine. There is practically no filing at the cotter when taken from the milling machine, only the sharp edges remaining to be removed with a smooth file.

Another example of milling suitable for the "Lincoln" and upright plain type of machine is the brake lever for an automobile shown in Figs. 22 and 23. This is a mild steel stamping, with round edges, 2 ft. 6 ins. long with a simple form cutter of the correct radius as shown. These levers are milled on both edges in exactly fifteen minutes each at a cutting speed of 46 ft. per minute, and a table feed of 3 ins. per minute. Of course there is not much to remove, but it would take a planer at least one-and-a-half hours to perform the same piece of work to a very indifferent finish.

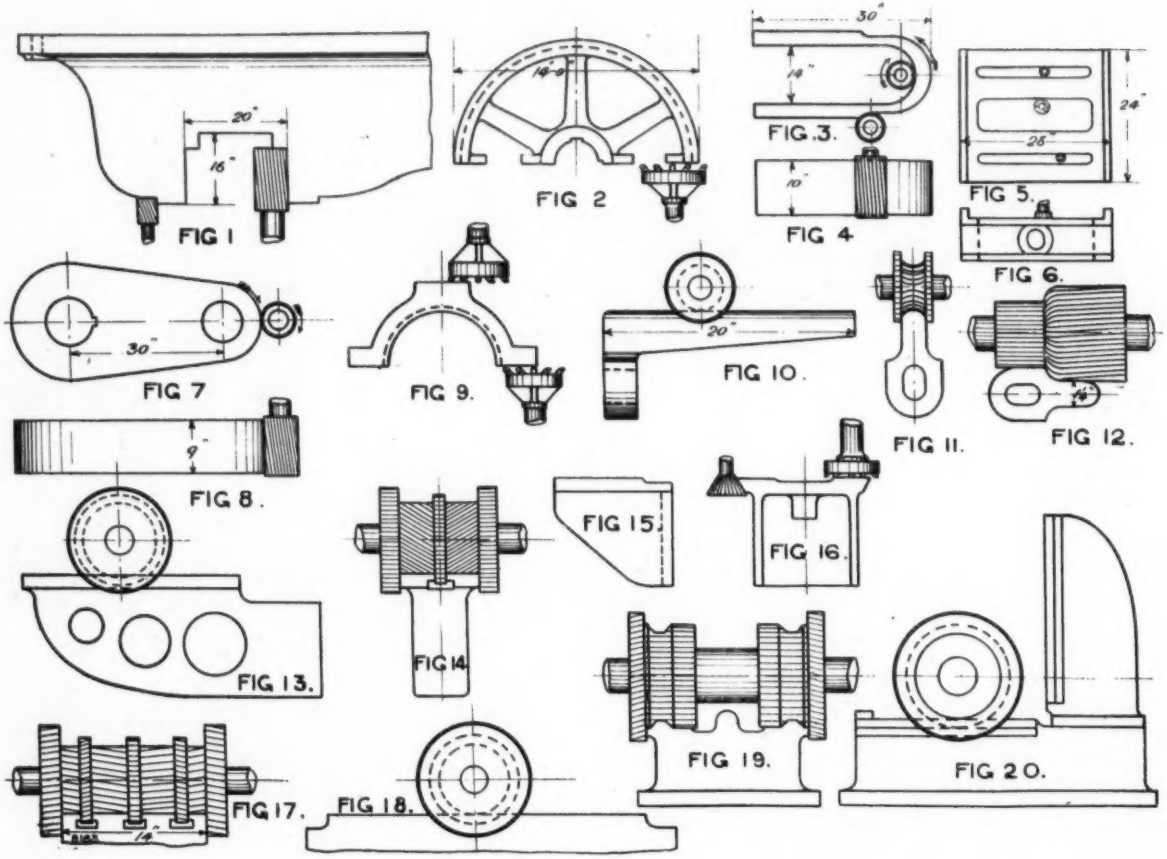
Figs. 17 and 18 show a gang of cutters operating on a plain milling machine table. The two outside cutters finish the table to width, the four small cutters operate on the top of the table, whilst the three narrow cutters gash the gored T slots to width, leaving them to be finished with the T slot cutter shown in Fig. 29 on a vertical machine. The gang cutters when not used for the job, are stored away complete with their arbor, as by using them singly on general work they lose their size owing to the necessity for constant grinding and resharpening. This is a very important item with expensive gang cutters which should be borne in mind.

It formerly took twelve-and-a-half hours to plane this table up, it is now milled in four hours at a cutting speed of 35 ft. per minute and a table feed of 1¼ ins. for roughing and 1¾ ins. for finishing.

Figs. 13 and 14 show a planer housing arranged to be gang milled on the face of a heavy horizontal slab miller of the "Ingersoll" and "Newton" types, at a table feed of 2½ ins. per minute at about 60 per cent. economy, as compared with the planing machine.

Figs. 19 and 20 show a very excellent piece of work done on a heavy slab miller in the shape of a bed for a gear hobbing machine, only four cutters being required to perform this work, including the sliding ways for the table shown on each side. These are completed with the two form cutters shown, spaced the exact distance apart—which is a very vital point and saves a lot of bedding when fitting the table. The latter is also gang milled with suitable cutters to fit on the ways. The housing shown in Fig. 20, and also the head for carrying the cutter spindle are milled in a similar manner. Fig. 1 shows the crank-shaft end of a large stationary engine bed, the adjustable bearing gap being milled out to size by a large and extremely powerful machine of the milling and boring type. The cutter is fed to the work, the latter remaining stationary, the bed end is milled complete for the bearing and cap in ten-and-a-half-hours, a job that would be very difficult to perform on a planing machine, however powerful.

Fig. 2 shows part of a large rope


20"
16"
FIG 1
14"
FIG 2
30"
16"
FIG.3.
10"
FIG 4
28"
24"
FIG 5.
FIG 6.
30"
FIG 7
FIG 9.
20"
FIG 10.
FIG 11.
FIG 12.
9"
FIG 8.
FIG 13.
FIG 14
FIG 15.
FIG 16.
FIG 17.
FIG 18.
FIG 19.
FIG 20.

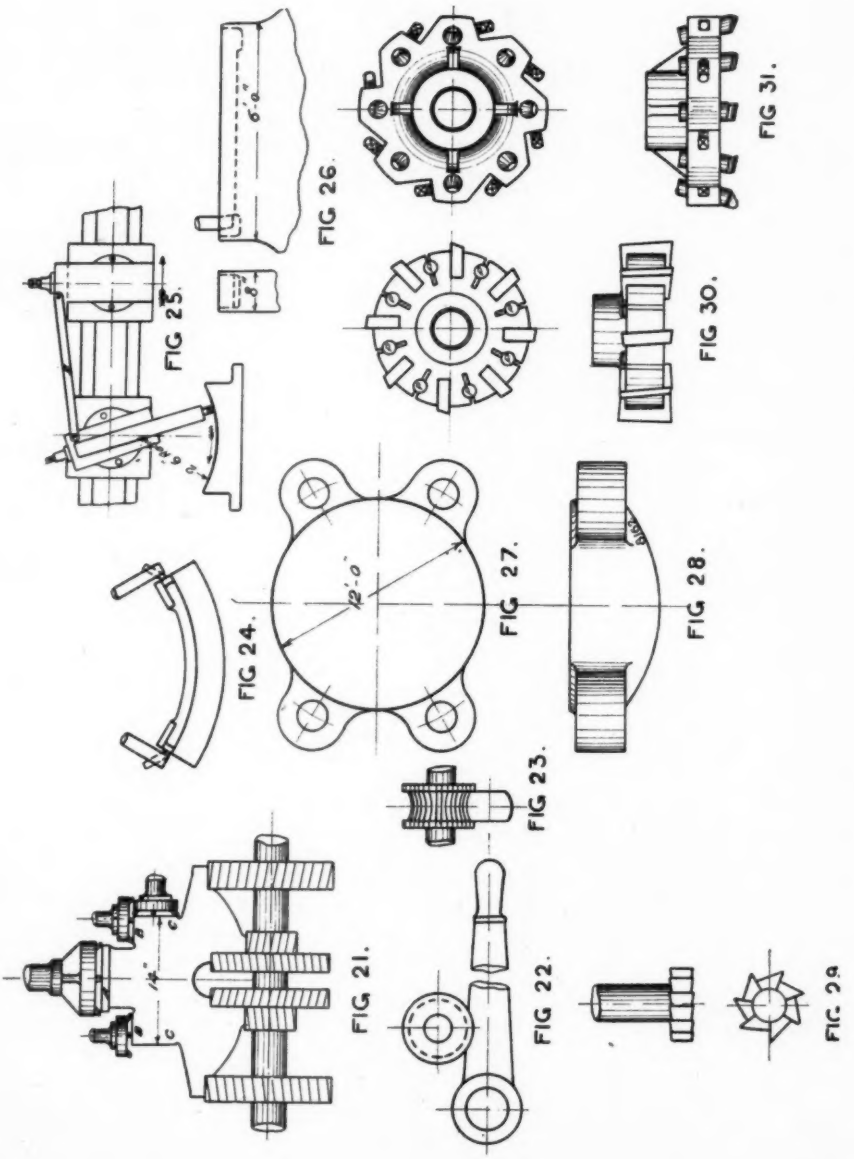


FIG 21.
FIG 22.
FIG 23.
FIG 24.
FIG 25.
FIG 26.
FIG 27.
FIG 28.
FIG 29
FIG 30.
FIG 31.
12'-0"
6'-0"

driving fly-wheel, cast in halves, being milled across the joint in the same machine with an inserted tooth cutter. In this case also a great saving is effected as compared with the planer. The latter machine has to travel across the entire face, and thus quite 75 per cent. of the stroke is wasted, as reversals and very short strokes on heavy planers are not to be recommended, whereas with the miller, only the surfaces actually operated on are traversed. The keyways are also cut in at the same time with an end milling cutter the same diameter as the width of key, viz., 4 ins., and thus much time is saved in that direction also.

Fig. 9 shows an eccentric strap being milled in the same manner, at a great saving compared with planing.

The vertical spindle miller has been developed to include a large field of operations from keyway cutting up to work of very large dimensions. Figs. 3 and 4 show a large forged steel strap for a connecting rod, milled all over on a vertical spindle machine. The top and bottom are milled first with inserted tooth cutters, the strap being then finished inside and out in the manner shown at a cutting speed of 45 ft. per minute, and a feed of 2 ins. per minute. The time taken is now twenty-one hours whereas, formerly, to plane and slot these straps, took twenty-nine hours.

Figs. 5 and 6 show a large double-ported slide valve, the parts of which are milled to size in a vertical spindle machine, after the valve has been planed all over, on a high speed planer, cutting at 35 ft. per minute. This is an instance where both the planer and the miller can be used to advantage on the same piece of work for different operations, as it has been found that excepting the port holes these can be planed cheaper than by milling.

Figs. 7 and 8 show two large steam engine cranks of forged steel, planed top and bottom, and then finished all round on a large vertical spindle machine with a circular milling attachment. This machine has two spindles, the crankshaft and pin holes being bored both at the same time after the milling is completed, thus saving the time of extra handling—no small item where heavy weights are involved.

Figs. 15 and 16 show a knee or table support for a milling machine being milled on a vertical spindle machine, the angular cutter operating down the sides as shown.

In Fig. 21 one of the most beautiful examples of milling is shown. It consists of an aluminium crank case for a 30-h.p. motor car engine, 2 ft. 6 ins. long. The top face marked *A* is first milled, the faces *B* being operated on at the same setting. *A* is then bolted against an angle plate, and the camshaft cover faces, *C*, are completed. The cutting speed is 580 ft. per min., and the feed 10½ ins. per min. The case is then taken to the slab miller and the bottom milled out complete with gang cutters as shown. These engine cases, which formerly took 12 hours to plane, are now milled in 5 hours.

The milling machine is far better adapted for working aluminium than the planer, by virtue of its having a much wider range of speeds and feeds.

The "Universal" milling machine is a masterpiece, and can fairly claim to be the king of millers, if, indeed, not of all machine tools, but being chiefly designed for tool room work, it can scarcely be said to enter the field of competition with the planer. American tool makers especially, have paid particular attention to this type of machine, and it is chiefly due to their efforts that it has reached its present high state of perfection.

Planers may be divided into two types, viz., horizontal and vertical, although few machines of the latter type exist compared to the former. The design of the planer has been much modified during the past few years, chiefly due to the advent of high speed steel. Whereas a few years ago it was considered good standard practice to work at a cutting speed of 20 ft. per min. and return at 40 ft., it is now no uncommon thing to see planers cutting at 40ft., and in some cases 50 ft., per min. and returning at 200 ft. per min. Machines of this type can, on certain work, more

than hold their own against the milling machine, and on this account will continue to keep up their established position in the shops. More particularly does this apply to the heavier branches, for instance, an example is shown in Fig. 24, which represents a segment of a large rope-driving flywheel rim being operated on at both ends at the same time by two saddles on the cross-slide. Eight of these segments—sufficient to build a wheel—are placed in a row on the machine table, being thus planed all at one setting, thereby ensuring extreme accuracy, cutting at 25 ft. per min. and returning at 50 ft., using high speed tools. This is a very heavy piece of work which no milling machine could perform in the time taken to plane them.

Fig. 25 shows a very interesting piece of work in the shape of a former plate, 10 ft. 6 ins. long, for a vertical plate bending machine being planed out to a radius of 2 ft. 6 ins. in the manner shown. The left-hand tool box is set centrally above the work and the swivel head-bolts slacked; the saddle is then locked in position and the rectangular bar, *A*, is connected to both the tool boxes. The right-hand tool box then commences to travel in the direction shown by the arrow, and by so doing drags the cutting-tool through the required arc. This is a job which no milling machine could accomplish satisfactorily with such primitive equipment.

Fig. 26 shows the slides of a horizontal engine which we still plane out to advantage, as milling cutters cannot be got in at the end, owing to insufficient clearance.

Figs. 27 and 28 show a large hydraulic press top cover weighing 50 tons, which is planed on a large machine operating four cutting tools at the same time—two in each tool-box on the saddle. We have not yet found a quicker method.

The concluding sketches, Figs. 30 and 31, show two types of inserted milling cutters for use on heavy milling machines. Fig. 30 is a type largely used on vertical spindle machines; the cutters are given 5 deg. forward rake and are held in position by the taper pegs, *P*, driven in holes, which are gashed through with a slitting saw as shown, to give the necessary spring under the wedging action. This cutter gives good results, if ground accurately, on certain classes of work, but is more expensive to make than that shown in Fig. 31, which are simply round cutters secured by screws. The holes for carrying the cutters are not bored with any forward rake, that being ground on the cutter itself. This type of cutter is largely used on heavy rough work and also in smaller sizes on aluminium, where it scores heavily over the flat-tooth variety. The latter is not designed to allow of sufficient clearance on the bottom which is absolutely necessary on aluminium, otherwise the chips get under the cutters and produce a very rough finish on the work.

Weighing the profit-earning qualities up of the planing and milling machines it is generally conceded—and not without reason—that the miller predominates, but at the same time, the planer still leads on certain classes of work, such as long straight surfaces, plate edge planing, and lathe-bed planing, more particularly on the larger sizes, also planing the slides of their own beds up, as well as tables, &c. It may safely be concluded that although the milling machine is pre-eminent, the planer will always find favour on certain classes of work.

The Fixation of Atmospheric Nitrogen.

By F. HOWLES, M.Sc.

THE sources of supply of combined nitrogen, *i.e.*, nitrogen in a form which can be used in the arts, and also in agriculture, are limited—the available supplies, at any rate of nitrate, are rapidly becoming exhausted, whilst, for both purposes, the yearly consumption is increasing at an enormous rate.

The great outlet for sodium nitrate, or Chili saltpetre, is found in agriculture. In 1906, 1,240,000 tons of this product were used for this purpose, the balance of about 400,000 tons being consumed in the chemical industries.

As the area of land, suitable for the profitable culture of cereals, cannot be indefinitely extended, and as the population is rapidly increasing, the yield of grain per unit of land must be increased. In this connection it is interesting to note some experiments of Lawes, who found that the yield of grain was more than doubled after manuring a starved land, on which wheat had been grown, with 5 cwt. of nitre per acre. Sir William Crookes estimates that, in thirty years, 12,000,000 tons of nitre per annum will be required to meet the continually increasing requirements of the "wheat-eaters," and M. Vergara, taking into consideration the increasing consumption during the last few years, has calculated that the nitre beds of Chili will be exhausted in 1923.

The second source of combined nitrogen is represented by the 700,000 tons or so of ammonium sulphate, which is yearly produced by the distillation of coal. The greater portion of this product also is used in agriculture. It is, however, slightly less efficient—reckoned on a nitrogen basis—than sodium nitrate as a manure, since it must, before assimilation by the plant, first be converted into nitrates by the bacteria of the soil, and during this process a certain proportion of the combined nitrogen is liberated and escapes as gas. This represents a direct loss.

As no very great—certainly no permanent—addition to the world's supply of combined nitrogen can be looked for from this source, and as there are no indications of the natural product occuring in any other part of the world, the attention of inventors has been drawn to that great reservoir of nitrogen, the atmosphere, which is estimated to weigh about five trillions of tons, four-fifths of which consists of nitrogen.

In the following pages I propose to show how this great store of nitrogen has been successfully drawn upon, and the methods that have been proposed, or are in actual operation, for the fixation of this element.

It has been known since the time of Priestly and Cavendish that nitrogen could be induced to combine with oxygen under the influence of the electric discharge, and that, from the oxides of nitrogen so formed, nitric acid and nitrates were produced by solution of the gases in water and alkalies respectively. These results, however, were only of academic interest, the small amount of electrical energy consumed in producing the high tension discharge excluding the application of this method for technical purposes. With the development of modern electric appliances, the problem assumed a more promising aspect, and in 1897 Sir William Crookes exhibited a flame produced by the passage of a high tension alternating current in air between platinum electrodes. In this flame the oxidation of nitrogen takes place and large quantities of nitric oxide are generated. Lord Rayleigh also, in 1897, studied this phenomenon, and in 1898 a

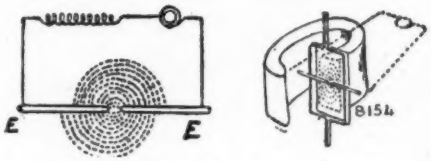


FIG 1.

series of investigations were undertaken by Mr. McDougall and myself in order to determine the most favourable conditions for the combustion of nitrogen in the high tension flame and the subsequent preparation of nitrates on a commercial scale. Our experiments indicated that, for the economic combustion of nitrogen by means of electrical energy, a number of conditions must be observed, such as the form of furnace, the rate and temperature of the air supply, the strength and voltage of the current producing the arc, &c.

On the temperature to which the air is raised depends to a very great extent the concentration of nitric oxide in the gases leaving the electric furnace, for it can be demonstrated both by dynamic reasoning and actual experiment, that the higher the temperature of the reaction the greater is the velocity of reaction and also the volume percentage of nitric oxide produced. It is thus essential to use an arc of the highest possible temperature. It is also very necessary to cool the gases leaving the hottest part of the arc, as rapidly as possible, in order to prevent dissociation, in the cooler parts of the arc, of the nitric oxide produced in the hottest part. That is to say, one must endeavour to produce such a rapid temperature fall that the gases retain that nitric oxide concentration which they possessed at the highest temperature to which they were subjected. Of course, in practice this is impossible, although so far 79 per cent. of the theoretical yield has been obtained, and it is highly probable that in the near future this amount will be increased.

Various methods of producing high tension electric arcs of great power have been suggested, but I propose to treat of two only, which will serve as representative types.

In 1903, an English patent was granted to Eyde and Birkland, for an apparatus in which large quantities of electrical energy could be used for the purpose of effecting reactions between gases at high temperatures. The utility of the apparatus depended upon the fact previously established, that, when a high tension flame played between electrodes, situated in a magnetic field a spreading of the flame resulted, which, when an alternating current was used, assumed the form of an oscillating disc, diagrammatically represented in Fig. 1, where the electrodes E—are alternately positive and negative.

Working on these lines, Eyde and Birkland designed an electric furnace in which an arc absorbing 500 k.w. played between water-cooled copper electrodes, situated in a powerful magnetic field. An arc of more than one metre in diameter, and 35 to 40 m.m. thick is thus produced, with a working potential of 5000 volts. The construction of the furnace will be readily understood from Fig. 2.

The arc chamber is shown at 2, the electrodes at 7, the magnets at 12, and the air inlet and outlet, at 15 and 16. The field magnets are excited by means of a direct current, and consume an amount of electrical energy equivalent to 10 per cent. of that used in the arc. The water-cooled electrodes absorb about 7·5 per cent. of the energy of the flame, and are removed for repairs after being in operation for about 300 hours. Three 500 k.w. furnaces are now actually in operation at Notodden, 1500 c.m. of air per hour are passed through each furnace, and the exit gases contain 2 per cent. by volume of nitric oxide, which corresponds to a yield of 600 kilos. of anhydrous nitric acid per k.w. year. One of the 1000 k.w. furnaces for use at the new works where 27,000 e.h.p. will be produced hydraulically, is shown by Fig. 3.

Another method of producing powerful high tension arcs is used by the Badische Anil und Soda Fabrik. The apparatus

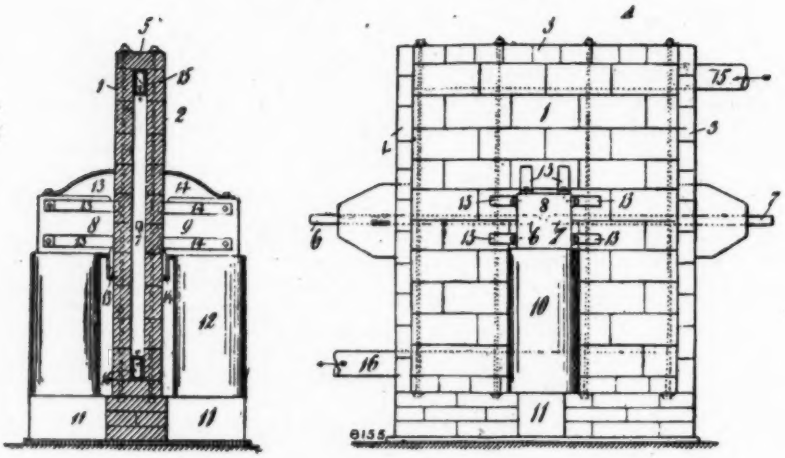


FIG. 2.

(Fig. 4) consists essentially of an iron tube, one metre or more in length, in which an insulated electrode is situated at one end, and a single electrode, electrically connected to the tube, is inserted at the opposite end. On passing a current of some few thousand volts, an arc strikes between the insulated electrode, and the wall of the iron tube adjacent to it. If now, air, with a whirling motion, be blown into the tube, the arc travels along the wall to the opposite electrode, and as long as the current of air be maintained, the arc continues to burn steadily between the electrodes. Several insulated electrodes, each in separate tubes, the latter, however, all leading into one common chamber, in which is situated the electrode electrically connected with the tube, are also used. It is also found that, with the use of either single phase or polyphase currents, several arcs in one tube can be obtained, burning quietly side by side, and uniting at the opposite end of the tube. The iron tube is earthed so that no danger is incurred by touching it. 100 k.w. of electrical energy have been employed in each arc. The apparatus is extremely simple, and should good yields of acid be obtained, there appears to be no reason why the process should not be a commercial success.

Of the methods suggested for augmenting the yield of nitric oxide per unit of electrical energy consumed, that of increasing the pressure of the gases surrounding the arc would appear to offer the most promising results. Under increased pressure, the gases offer a greater resistance to the passage of the current, the temperature of the arc is thus raised, and concurrently the amount of nitric oxide produced.

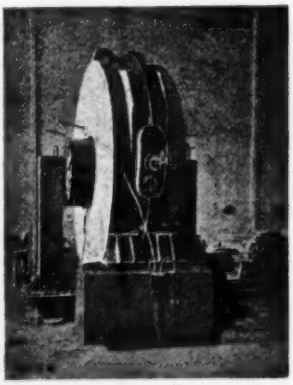


FIG. 3.

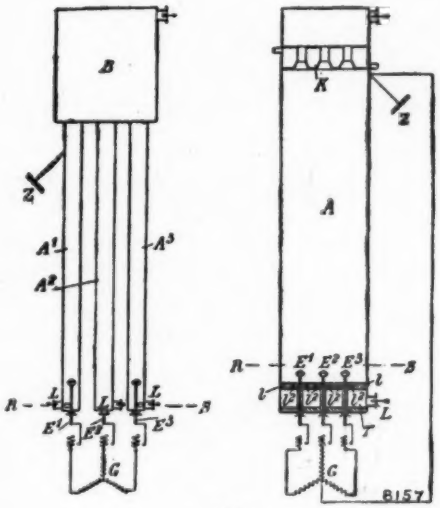


FIG. 4.

A^1, A^2 and A^3 represent iron tubes, in which the high tension arcs play between electrodes E^1, E^2 and E^3 and the common end B of the tubes where the flames unite. The tubes are earthed at Z, and the electrodes are fed by the polyphase current from G. Air enters the tubes at L, and leaves at the opposite end charged with nitric oxide.

In the tube A, three flames, springing from the electrodes E^1, E^2 and E^3, and uniting at the opposite end, burn quietly side by side. The air is introduced into the tube through the false bottom P, and being evenly distributed exerts no disturbing effect upon the flames. Before leaving the tube the gases are cooled by passing through the condenser K.

After leaving the furnaces, the gases possess a temperature of from 600 to 700°C and contain two or more per cent. by volume of nitric oxide, which, as the temperature falls, becomes rapidly converted, by means of the excess oxygen present, into nitrogen peroxide. The gases are reduced in temperature to 200°C by passing through a steam boiler, and are further cooled to 50°C before reaching the series of absorption towers. Down these towers, water or dilute acid flows, and in the case of the last tower of the series, milk of lime, as it is difficult to absorb the traces of nitrogen peroxide here remaining in the gases by means of water alone. The acid from the base of the second tower is raised to the top of the first, that from the third tower, to the top of the second, and so on. In this way, the strongest acid is obtained in the first tower, and contains from 50 to 60 per cent. of anhydrous nitric acid, which, however, is not free from nitrous acid. At present it is impossible to prepare a stronger acid than this, by the direct absorption of the nitrogen peroxide by means of water or dilute acid, and at Notodden, this acid is neutralised with calcium carbonate (limestone), the solution of calcium nitrate thus obtained is evaporated until a boiling point of 145°C is reached, corresponding to a concentration of from 75 to 80 per cent. of calcium nitrate, and containing 13·5 per cent. of nitrogen. The product is then run into iron drums of about 200 litres capacity, where it solidifies, and in that form, appears on the market.

The fixation of atmospheric nitrogen has been accomplished by Frank and Caro by a process yielding quite another class of products to those just considered. Their method depends upon the fact that the alkaline earth carbides, when heated to from 700°C to 1,000°C in an atmosphere of nitrogen, yield cyanamides, in accordance with the following equation:—

$$R\,C_2 + N_2 = R\,CN_2 + C$$

where R = calcium or barium. This compound only is formed when calcium carbide is used, barium carbide, however, yields a mixture of barium cyanamide and barium cyanide.

When calcium cyanamide is treated with water or steam, ammonia is evolved, in accordance with the following equation:—

$$Ca\,CN_2 + 3\,H_2O = Ca\,CO_3 + 2\,NH_3.$$

The same reaction takes place when land is manured with this substance, the moisture in the soil slowly disengages ammonia, which, after conversion into nitrates, by the soil bacteria, is made available as plant food, and serves the same purpose as Chili saltpetre or artificial nitrates.

The manufacture of calcium cyanamide on the large scale has been undertaken by the Cyanid Gesellschaft in conjunction with the Societa Italiana par la fabbricazione di prodotti azotati. A large factory has been erected at

Piano d'Orta, near Pescara, in Italy, operated by water power. The yearly production is 4,000 tons, but extensions, which are being undertaken, will increase the capacity of the factory to 20,000 tons. In Dalmatia, Switzerland, the Rhone Valley, Norway, America and Germany, factories are also being planned, or are actually being built, for operations on a still larger scale.

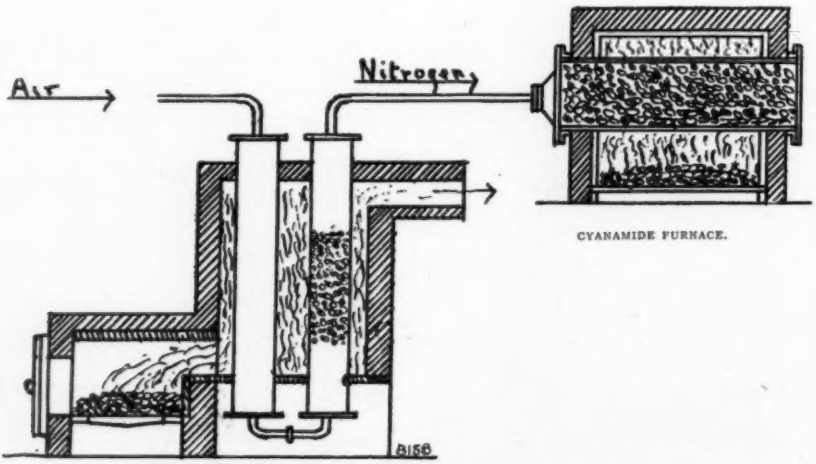
The nitrogen required for the process is prepared, either by the fractional distillation of liquid air in accordance with the "Linde" method, or by passing air over heated finely divided copper, the oxygen is fixed by the copper, yielding the oxide of the metal from which, by reduction with producer gas, copper is regenerated, and is again available for the same cycle of operations. A diagrammatic view of a plant working on this principle is shown in Fig. 5.

The gas is then conducted into closed retorts containing calcium carbide, and heated from the outside to a temperature of from 700°C to 1,000°C. The absorption of the gas proceeds energetically with considerable rise in temperature. Throughout the operation, the progress of the nitrogen absorption is indicated by a gas meter, and when this shows that no further absorption is taking place, the contents of the retort are discharged, with exclusion of air, into air-tight metal cylinders, and when cold, are pulverised and packed. The black substance obtained by this process, contains from 19 per cent. to 21 per cent. of nitrogen, and has the following average composition :—

Calcium cyanide, 57 per cent.; caustic lime, 21 per cent.; carbon, 14 per cent; silica, 2·5 per cent.; oxide of iron, 4 per cent.; lime, combined with carbon, sulphur and phosphorous, 1 per cent.

Siemens and Halske prepare calcium cyanamide by leading nitrogen directly into a mixture of coke and lime, heated in an electrical resistance furnace, thus avoiding the manufacture of calcium carbide as a preparatory process. The furnaces are represented by Figs. 6 and 7. There are double walls between which the nitrogen circulates, and then passing through channels into the furnace, it evenly permeates the charge. The furnace represented by Fig. 7 is 6 m. long, 3 m. broad, and 2 m. high.

The product from these furnaces, however, contains only 12 per cent. to



NITROGEN FURNACE. CYANAMIDE FURNACE.

FIG. 5.

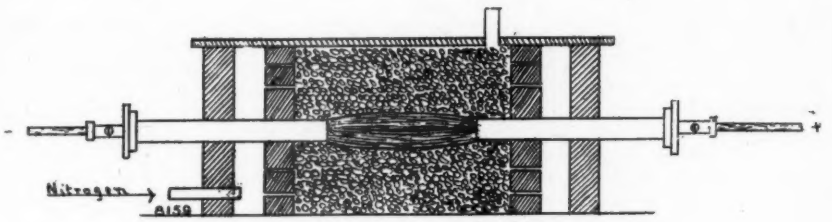


FIG. 6.

15 per cent. of nitrogen, against the 20 per cent. to 22 per cent. contained in the cyanamide obtained by the Frank and Caro process.

In order to obtain ammonia or ammonium sulphate from the calcium cyanamide thus produced, the latter body is placed on superimposed trays, in a tower through which steam is blown. The evolved ammonia is absorbed in sulphuric acid, and the crystals of ammonium sulphate worked up in the usual way. The special plant used in this operation is represented by Fig. 8.

By this means, 99 per cent. of the nitrogen contained in the cyanamide is obtained.

If the ammonia, instead of being absorbed in sulphuric acid for the preparation of ammonium sulphate, be mixed with air, in quantities sufficient to completely oxidise it, and then passed through tubes heated to redness, containing platinum or the allied metals, or oxides of the heavy metals, nitric acid is produced. The best results are obtained by using compact platinum, covered with platinum black. By a combination of these processes, it is thus possible to prepare ammonium nitrate, a product containing 35 per cent. of combined nitrogen, and which finds a direct application in the manufacture of explosives.

The continent is being overrun by companies seeking water power available for the production of artificial nitrate and cyanamide. The Badische Anil und Soda Fabrik, conjointly with the Berlin Anilin Fabrikation A—G, and the Elberfeld Colour Works have participated in the formation of two Norwegian companies for the manufacture of artificial nitrate. The capital of about £1,900,000 will be subscribed half by the above German companies and half by a Franco-Norwegian syndicate.

In addition to the Piano d'Orta Company mentioned above, two other Italian companies have lately been formed, the Societa Generale Elettrica del Adamello, and the Dynamo of Milan, each with a capital of £400,000 subscribed by Italian, French and Swiss bankers.

At the present time, it is essential in

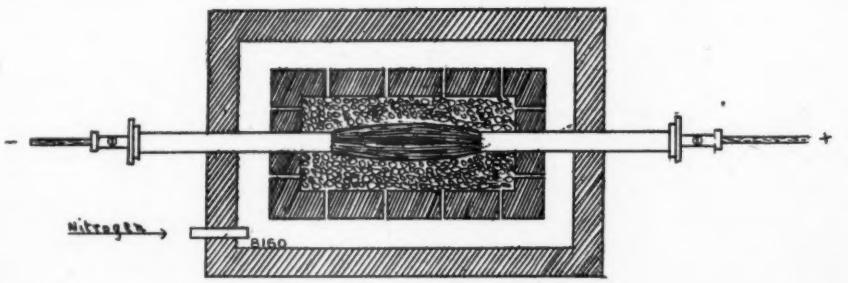


FIG. 7.

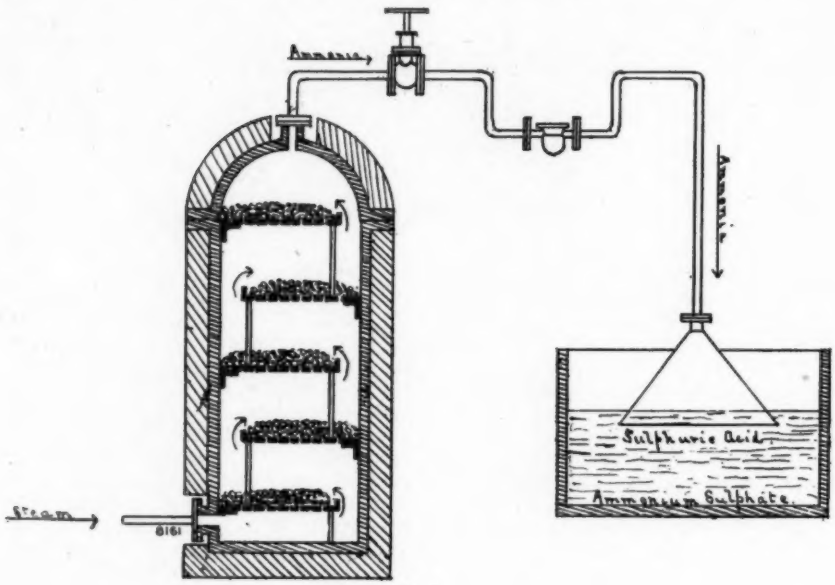


FIG. 8.

order that synthetic nitrates shall be able to compete with the natural product, that a cheap source of electrical energy be available. In Norway, Switzerland, Upper Italy and some parts of Austria, this is provided for, by the large waterfalls which occur in these parts. But in this country, where water power cannot be obtained, some other means of generating cheap electrical energy must be resorted to, if this most important industry is to obtain a footing here. It is to the gas engines, especially those run on blast furnace gases, that we must turn for the economical generation of power. The use of this motor, in conjunction with these gases has proved a commercial success. On the continent, engines up to 4,000 h.p. are now being built, designed for use with blast furnance gases.

When "Mond" producers are used with fuel at 7*s.* per ton, and reckoning £14 per e.h.p. as the cost of the outfit, the k.w. year costs £3 13*s.* 6*d.* With blast furnace gases, this cost should be considerably reduced, and should approach if it does not fall below that for water power, which, among the lowest estimates, is given at £2 per k.w. year.

In 1906, nearly 10,000,000 tons of pig iron were produced in this country, and when gas engines are used, it is estimated that, after providing for all the power necessary for the operation of the works such as hoisting, blowing, &c., there remains a surplus of from 500 h.p. to 1,000 h.p hours per ton of iron made. Assuming an average of 750 h.p. hours, then with an hourly production of 1,250 tons of iron, the total available surplus power amounts to 937,000, or nearly 1,000,000 h.p.

With a production of one ton of sodium nitrate per 1·6 e.h.p. year, our blast furnaces would supply about 580,000 tons of nitre, or about 470,000 tons in excess of our present requirements.

If iron smelters found no other use for their surplus furnace gases, an enormous industrial saving would be introduced by the utilisation of this

surplus for the production of cheap electrical energy which might be used in the electro chemical industries. In any case, the power derived from such a source, would be the cheapest obtainable in this country.

In conclusion, it will be interesting to compare the cost of power derived from various sources, and also the cost per kilo of combined nitrogen, obtained by the two principal electro-chemical methods, and for this purpose, the following tables have been compiled.

For these comparisons, the cost of electrical energy has been taken as £2 per k.w. year, which is the estimate at the Notodden installation.

Although with 1 k.w. year, two tons of carbide (= 400 kilos. of fixed nitrogen) are obtained, and the same power yields only 0·6 tons of nitric acid (= 133·3 kilos. of fixed nitrogen) the cost of one kilo. of fixed nitrogen in both cases is approximately equal, since, in the former case, there are additional manufacturing costs, among which may be mentioned the lime and carbon required for the fixation of the nitrogen and the necessity of freeing atmospheric air from oxygen for the production of the nitrogen utilised in the process.

Thus, as the natural supplies of the greatest fertiliser show indications of becoming exhausted, science steps in. and points out the way of utilising the vast store of elementary nitrogen in the atmosphere for the artificial production of the nitrogen compounds, of which both the agricultural and chemical interests now stand so much in need.

COMPARATIVE COST OF POWER DERIVED FROM VARIOUS SOURCES.

Source of Power.	Cost per k.w. Year.
	£ s. d.
Water	£4 0 0 (average) £2 0 0 (Notodden)
Steam	6 0 0 (S.E. Lancs.)
Mond Gas	3 13 6 (fuel 7s. ton)
Blast Furnace Gases at 2s. per 100,000 cubic feet ...	2 13 4

COMPARATIVE COST OF ONE KILO OF COMBINED NITROGEN IN THE TWO ELECTRO-CHEMICAL PRODUCTS, AND ALSO IN THE COMMERCIAL SALTS.

Product.	Value per ton (1,000 kilos).	Value of 1 kilo. of combined Nitrogen.
	£ s. d.	s. d.
Cyanamide (20 per cent. Nitrogen)	10 0 0 (at works unpacked)...	1 0
Electro-chemical Nitric Acid (22·2 per cent. Nitrogen)	6 17 6 (at works unpacked)...	7½
Electro-chemical Basic Calcium Nitrate (13·5 per cent. Nitrogen)	4 6 0 (at works unpacked)...	7·6
Chili Nitrate (16·5 per cent. Nitrogen)	10 7 6	1 3
Ammonium Sulphate (21·2 per cent. Nitrogen)	12 10 0	1 2½
Chemical Nitric Acid (22·2 per cent. Nitrogen)	20 0 0	1 7½

The Cape to Cairo Railway.

An entire absence of navigable rivers and the difficulty and expense of road-making over the vast, sandy and waterless stretches of country have rendered the construction of railways in South Africa of premier importance. The politics of the country have devolved upon railways, and ministers have come and gone on their "railway policy." It is, therefore, fitting that such a far-seeing Imperial statesman as the late Cecil John Rhodes should have early discovered that railways must follow hard upon the tracks of the pioneer. The difficulty lay in the expense, for, in the earlier days, the conservatism of the country's engineers had the tendency to involve the various Colonies in the construction of railways of a heavier and more expensive type than the volume of traffic warranted. As indicative of this, it may be mentioned the railways of the Natal, Transvaal and Orange River Colonies have cost £15,000 a mile, those of the Cape Colony £10,000 a mile, while the line with which this article deals has cost £3,000 a mile to construct.

In 1889 the northern terminus of the Cape Colonial Railways was at Kimberley, 647 miles from Cape Town, and it was in this year and from this point that Mr. Rhodes entered upon his great trans-African railway scheme for the opening up of the vast hinterland now known as Rhodesia. His first step was the building of a line to Vryburg, 127 miles north of Kimberley, and thus overcome the difficulties of transport across the Vaal and Hartz Rivers, and over the heavy, sandy and waterless roads intervening.

In this enterprise Mr. Rhodes was fortunate in securing the services of a Cape Government engineer, who had realised that in the development of a new country by means of the railways, economy and rapidity of construction were of the first importance, and, exclusive of the Vaal River bridge, the 127 miles were laid in under twelve months, at a cost of £4,500 a mile. Upon completion this line was purchased by the Cape Government Railways and added to their main line.

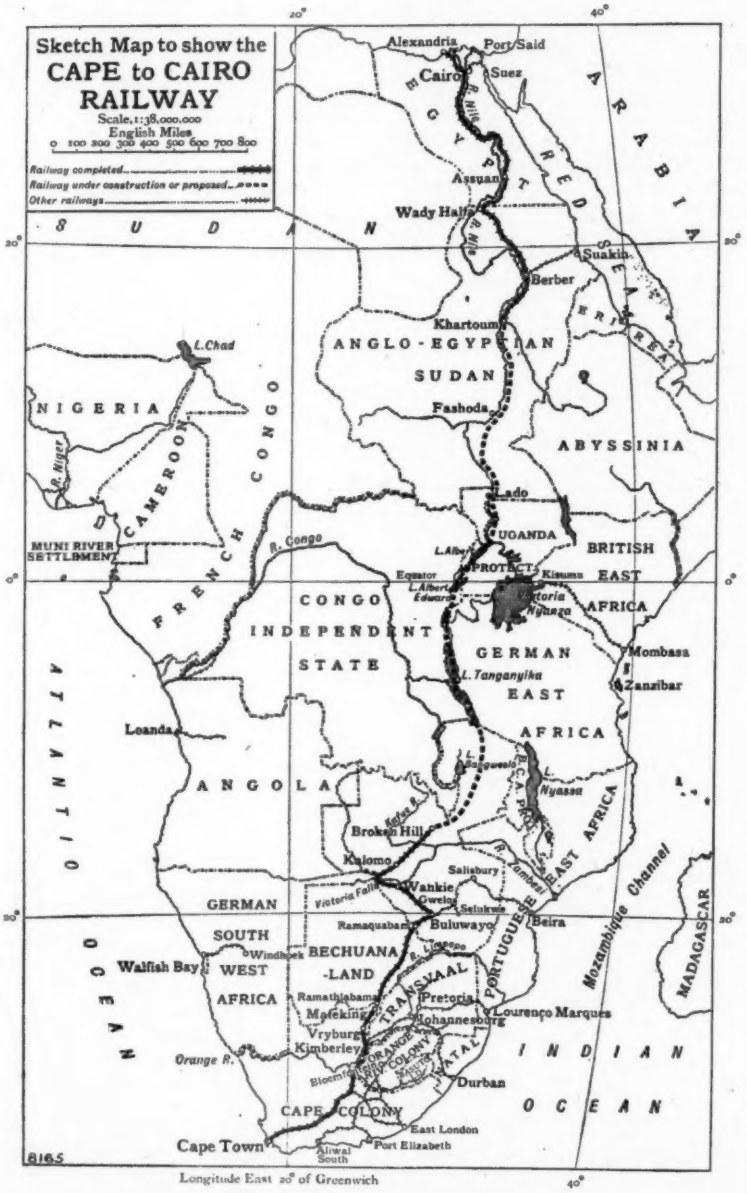
A further advance was made in August, 1893, and the 96 miles from Vryburg to Mafeking was completed in October, 1894.

Meanwhile the pioneer expedition, which started from Kimberley in 1890 to colonise Mashonaland, had carried out its mission so successfully that the necessity for railway communication with the North became pressing, whilst the war, which resulted in the overthrow of Lobengula and the acquisition of Matabeleland, rendered further progress with the railway imperative.

Early in 1896 the railway construction started from Mafeking, and as the settlers in the new countries were then facing an outbreak among their cattle of the deadly rinderpest, which paralysed transport, a very critical situation presented itself, more especially as this disaster was followed closely by the Matabele rebellion.

Mr. Rhodes determined that the railway must reach Bulawayo before the end of 1897, and this the contractors, Messrs. Pauling and Company, Ltd., undertook to accomplish. Platelaying commenced on April 11th, 1896, and was pushed on with such rapidity that the rails reached Bulawayo on October 19th, 1897, the 492 miles of platelaying having been performed in 500 working days.

The intervention of the Anglo-Boer war prevented further progress for some time, but a forward move was commenced in May, 1901, and the first section of the Bulawayo-Zambesi line was opened to Wankie Coalfield, 1,572 miles from Cape Town, on December 1st,



(From the *Journal of the Society of Arts.*)

1903. Here a practically unlimited coal supply, so important a factor in railway development, was rendered accessible, thus obviating the delay and expense of hauling coal from the Transvaal mines, some 1,500 miles distant.

No time was lost in pushing forward with the construction, and on April 25th, 1904, the rails reached the Victoria Falls, 1,640 miles from Cape Town.

Before proceeding to give details of construction it may be desirable to mention the governing principles which were laid down for the guidance of the engineers in charge of the work, as well as some of the specifications to be complied with.

Rapidity of construction was of the utmost importance, as any delay might have seriously retarded the opening up of the country; economy was likewise essential, as an expensively constructed line would have made the provision of the necessary capital a difficult matter, besides which the prospect of the railway being able to pay interest had not to be lost sight of.

It was recognised that, providing gradients and curves were not sharper than is usual on lines of 3 ft. 6 in. gauge, it would be easy to improve the standard of the road from time to time, according to the volume of traffic. Banks could be raised and widened, additional waterways and more ballast provided, and new stations or crossing places built according to requirements.

The specification provided for all works necessary to insure a "line of railway which would be capable of effectually conveying traffic at a speed of twelve miles an hour on completion, and that the standard South African railway gauge of 3 ft. 6 in. be adhered to."

Provision was also made for the formation work of embankments and cuttings to be 9 ft. wide up to a height or depth of 1 ft., 10 ft. wide up to a height or depth of 3 ft., and for heavier work 12 ft. wide.

Ballast was only to be used on such portions of the line as was necessary to insure the safe running of trains during the rainy season, that is, where black, boggy soil was traversed, the quantity was not to exceed 15 cubic yards to the chain of 66 ft.

As regards platelaying it was specified: "It being of the utmost importance to push platelaying as speedily as possible, the contractor shall be at liberty to perform this work in the manner which he considers most desirable to effect the object in view. Temporary river crossing with 4 per cent. grades to be permissible."

Bridges and culverts were to be built of timber and of sufficient height only to carry off the flood water, the permanent masonry and ironwork being undertaken immediately after the opening of the railway.

Construction.—In laying the road very little regard was paid to formation, and wherever the surface of the ground was even it was followed, sleepers being packed up with a minimum of ballast to give a moderately smooth running top.

Platelaying.—The Vryburg-Mafeking section was originally laid with rails, 46¼ lb. to the yard, but was relaid with steel rails of 60 lb. section in 1902 to correspond with the standard adopted on the North extension. The Mafeking-Bulawayo section was constructed with steel "Vignoles" rails, in 30 and 35 ft. lengths, of 60 lb. section, connected by fishplates weighing 15 lb. per pair, with four bolts to each joint. Steel trough sleepers of Indian State pattern, 68¼ lb. each, laid 1940 to the mile, were used throughout. These sleepers answer very well, and when properly packed a good road can be easily maintained.

Wooden sleepers were impracticable owing to the ravages of white ants and other termites. Baltic creosoted pine cross-ties, protected from fire by sheets of zinc, are, however, used for crossings and over bridges and culverts. During construction this type of permanent way lends itself to rapid platelaying and alignment, as much as 4·1 miles having been laid down in one working day. Mile and quarter-mile posts are fixed throughout.

Ballast.—Owing to the dryness of the

climate and the adaptability of steel sleepers to almost any kind of ballast which would pack closely, no serious consideration of this item was necessary. All that was required was usually obtainable in the excavation of side drains, &c., and except where passing through the lower levels over loamy soils, ballast was not supplied in greater quantities than specified, viz., 15 cubic yards per chain of 66 ft. It was found that broken limestone and gravel, which was nearly always found by excavating at the side of the formation, made the best ballast. A sand belt of 80 miles is traversed on the Vryburg-Bulawayo section, and here the road was ballasted with the sand, which packs firmly. On the Bulawayo-Zambesi section the road is sand ballasted except for about 50 miles.

Land.—As regards land, a strip 300 ft. wide was allotted to the railway, *i.e.*, 150 ft. on each side of the centre line, except where more is required for stations and buildings. As a precaution against fire and to afford a better view of the line to enginemen the grass and trees within this strip are cut down.

Fencing.—The line is practically unfenced throughout, except in the vicinity of stations and buildings, and over a few farms traversed by the railway, the farmers having the right to demand fencing of the railway line through their farms upon payment of one-eighth of the cost.

Telegraphs.—The telegraph line was constructed at the same time as the railway and is the property of the Government. It serves for both railway and public purposes.

Bridges and Culverts.—Waterways of all sizes and descriptions were provided wherever necessary, the longest single span being 100 ft. with lattice girders. Concrete was largely used, mixed in the proportion of 6 stone, 3 sand, and 1 Portland cement. The larger bridges and culverts were built in random rubble, quarry-faced granite or sandstone. Lattice steel girders were used for the 75 to 100 ft. spans and rolled steel joists for 6, 9 and 12 ft. openings. Wrought iron pipes were largely used in place of small culverts and were faced at each end with rubble masonry. The following sizes were used: 12 in. diameter, 112 lb. per yard; 18 in. 173 lb.; 24 in. 278 lb.; 36 in. 467 lb.; 48 in. 736 lb.; 72 in. 1303 lb.

TYPICAL CUTTING.

Buildings.—All buildings originally constructed were of an inexpensive and portable character, generally of galvanised corrugated iron, lined with match

CHARACTERISTIC VIEW OF THE LINE

boarding. This step was fully warranted, as many of the buildings were erected at points which proved unhealthy, and it facilitated the removal of the structures to healthier sites or to points where traffic requirements became more apparent. Now that the exigencies of the railway working are better known, these temporary structures are being replaced by permanent brick buildings.

Water Supplies.—Water supplies were provided, as nearly as possible, at intervals of 40 miles. The water was pumped from a river, well or borehole and stored in wooden tanks where necessary. Cast iron overhead tanks of from 20,000 to 30,000 imperial gallons capacity have now replaced the wooden ones, while concrete walls have been constructed across many of the rivers to conserve the water during the dry season. Rain falls between the months of November and April and averages 24 in. a season, most of the rivers drying up for the rest of the year.

Stations and Sidings. — Telegraph stations are established at intervals of about 40 miles, with intermediate sidings or crossing places averaging ten miles apart. The traffic accommodation at these stations usually consists of a passenger loop, 1,122 ft.; freight loop, 1,056 ft.; dead end, 363 ft. in length, with passenger platform 264 ft. long, 14 ins. above the rail level and faced with brick. Quarters are provided as required for traffic and other resident officials, together with the usual offices, refreshment rooms, &c. Intermediate crossing places consist of a loop about 924 ft. between clearance pegs, usually with a dead end of 330 ft. No platforms or buildings are provided.

Method of Working.—Regular trains are run to a working time table, and each irregular train to a special train notice, showing the places where trains are appointed to cross or pass one another, while cancelled train notices are issued to set forth any regular train which will not run. Every train before leaving a telegraph station must be in possession of a written order to proceed, setting forth the point at which opposing trains, if any, are to be crossed, or following trains allowed to take precedence, the consent to and confirmation of such an order having been obtained by means of the telegraph from the telegraph station in advance. Signals are only provided at the telegraph stations.

Engine depôts are established at Vryburg, Mafeking, Bulawayo and Victoria Falls, trains between Vryburg and Mafeking (96 miles) being worked with single crews. Between Mafeking and Bulawayo, and Bulawayo and Victoria Falls (490 and 280 miles respectively) trains are worked by double crews in eight hour alternate shifts, the crew off duty being located in a caboose

containing lavatory and cooking conveniences. The same engine and crew perform the round trip of 980 or 560 miles respectively, and usually lay off for a few days before commencing another trip.

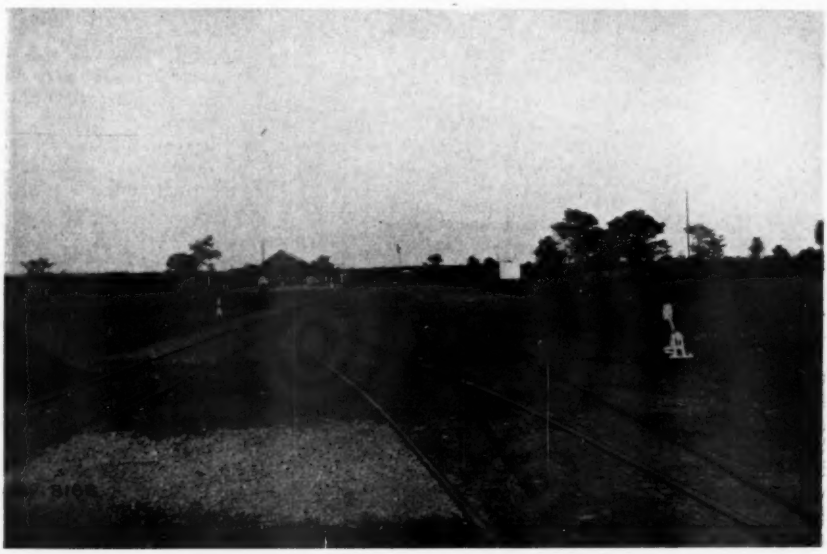
This system of running locomotives for a thousand miles continuously has its drawbacks, and the wear and tear on tyres and machinery is considerable, but the average run of 60,000 miles between visits to the shops may be considered satisfactory.

When the line was first laid engine depôts were built at intermediate points and short trips made with single crews, but owing to the unceasing prevalence of fever and sickness at these depôts the utmost difficulty was experienced in maintaining a staff, and this with the scarcity of locomotives, and then scanty water supplies and the heavy cost of upkeep of the depôts, soon rendered the introduction of long runs and the caboose system an absolute necessity. The intermediate engine depôts have now been abolished, except at Mahalapye, which is still retained for coaling purposes and as a depôt for an auxiliary locomotive in case of failure along the line.

Locomotives.—The standard locomotives are all of British manufacture, having eight coupled driving wheels of 4 ft. diameter, with a leading 4-wheel bogie. Cylinders 18½ in. diameter, 24 in. stroke, safety pressure on boiler, 180 lb. per sq. in., heating surface, tubes, 1,184 sq. ft.; firebox 131 sq. ft.; weight on each pair of driving wheels 12 tons; weight of engine and tender 93 tons, or in running order, about 120 tons; haulage capacity 500 tons; "Sheard" injector system, fitted below water level; tender capacity, coal 10 tons, water 27,000 gallons, average fuel consumption per mile run, 64 lb. Wankie coal.

Freight Cars.—There are several kinds of freight cars in use, the prevailing types being shewn in the table on p. 22.

Passenger Coaches.—Three classes of passenger stock are provided, viz., first, second, and third, fares for local journeys



STATION ON MAFEKING-BULAWAYO LINE, PLACED AT INTERVALS OF 40 MILES, SHOWING THROUGH TRACK.

Passenger loop, 1,122 ft. in length; freight loop 1,056 ft., and dead end 363 ft.

	Tare.	Load.	Length.
Wooden Bogie Trucks	11 tons	25 tons	34 ft.
Wooden 4-wheel Trucks	6½ ,,	15 ,,	20½ ft.
Covered Wood Bogies	13½ ,,	25 ,,	33½ ft.
Steel Bogie Trucks	12 ,,	34 ,,	36 ft. 10 in.

being on basis of 3*d*., 2*d*. and 1*d*. per mile respectively; in through journeys slightly less per mile is charged.

First class stock, 26 tons tare, length over all 60 ft., running on 4-wheel bogies. Each coach is fitted with five or six compartments with four berths each and has two lavatories, water closets, a through corridor and a balcony at each end. The second class cars are of similar build, with six compartments with six berths each. The third class cars are of the same dimensions with sleeping accommodation for sixty persons.

Couplings.—All couplings are of the central buffer type, with link and safety chain, while the lubricating system adopted is the wool and waste packed boxes with axle oil.

Speed.—The speed of trains is thirty miles an hour for passenger and twenty miles an hour mixed or freight.

Staff.—The line from Mafeking to Bulawayo is manned and worked by the Cape Government Railways, with executive headquarters at Mafeking, while the lines north of Bulawayo are similarly under the control of the Beira and Mashonaland Railways.

On the Vryburg-Bulawayo section the locomotive department is managed by a locomotive superintendent, under whose control is placed the care and upkeep of all engines, rolling stock, &c., together with the locomotive workshops, water-pumping operations, &c.

The engineer's department is controlled by a resident engineer, assisted by two district engineers, and responsible for the maintenance of permanent way, works and buildings, and all matters pertaining thereto. Under each district engineer are placed three road inspectors, each having an average of 100 miles of track under his supervision. Platelayers or gangers are placed under the inspectors, and have a length eight to ten miles. The gang consists of one platelayer, one assistant and from six to eight natives.

Repairs to stations, buildings, bridges, &c., and new additional works are carried out by a foreman-of-works and staff of artisans, also under the supervision of the district engineer.

Maintenance expenditure, embracing office expenses, supervision maintenance and renewals of permanent way, water supplies, repairs to stations, buildings, bridges, culverts, roads and signals cost £70 per open mile per annum on the Vryburg-Bulawayo section.

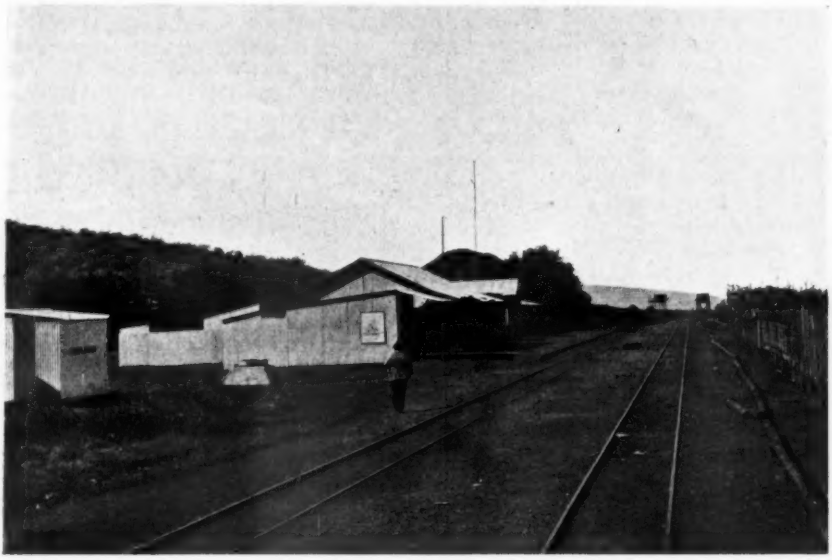
Traffic working is in the hands of a traffic manager; telegraph and postal work being also performed by the traffic staff at various of the smaller stations along the line.

Provision Train.—The difficulty of providing employees at roadside places with food and other necessaries was overcome by the establishment of a provision train, running once a month, and bringing supplies to employees' order from the nearest coast town at fixed contract prices.

Labour.—All unskilled labour, connected with platelaying and excavating, as well as coaling, portering and the like, is performed by natives, generally in small gangs, under the control of one white man. These natives, of whom, in normal times, there is a plentiful supply, are paid at a uniform rate of 2*s*. per diem, and are well adapted for this class of work. The ratio of white to native employees averages about one to four.

Artisans and skilled labourers are principally Europeans, while the technical and clerical staff has been to a large extent recruited from British railways.

Traffic.—The traffic going north consists of general merchandise, machinery, cut timber, live-stock, and imported grain and other goods. Traffic from the north is principally coal, rough wood, and pit timbers, hides, mealies, and other Rhodesia-grown produce. Large batches of natives proceeding from and to the gold and diamond mines and other labour centres pass frequently, on three days a week the entire journey from Cape Town to Bulawayo may be made in through cars of first or second class. A *train-de-luxe*, the Zambesi express, runs between Cape Town and Bulawayo weekly in each direction, conveying mails and passengers, and so timed as to afford connection with the Royal Mail steamers of the Union Castle line.



A STATION SHOWING THE TEMPORARY NATURE OF THE BUILDINGS FOR FACILITATING REMOVAL TO A MORE CONVENIENT OR BUSIER TRADE SPOT AS REQUIRED.

and are conveyed at reduced rates in specially fitted trucks.

On the Vryburg-Bulawayo section there are four regular trains per week each way—viz., one passenger (Zambesi *train-de-luxe*), two mixed, and one freight. Additional freight trains run as often as required.

Description of Route.—Presuming the traveller to have arrived at Cape Town, or one of the other seaboard towns, a daily train composed of comfortable corridor saloon cars, with sleeping and lavatory accommodation, will convey him to Kimberley without change, while

Leaving Kimberley, the heart of the diamond mining industry, the railway is carried over the Vaal River, near Fourteen Streams station, by a bridge 1,354 ft. long between abutments, consisting of ten spans of 130 ft. in the clear. Each span consists of two parallel wrought-iron lattice girders, 135 ft. 9 in. long by 14 ft. 4½ in. deep, and 2 ft. 6 in. wide over flanges, placed 15 ft. 6 in. apart centre to centre, supported on ironwork cylinder piers, the main girders being connected at their bases by cross girders to form the road bed, while each pair of main girders

is also connected overhead by four arched girders. This massive structure was blown up in the early stages of the Anglo-Boer war, and was rebuilt in 1901.

From the Vaal River the line ascends to the high plateau of Bechuanaland, which it traverses at an average altitude of 4,000 ft. above sea-level to Mafeking. Long tangents and easy grades rule, and no large bridges were necessary. The formation is sandy, with granite underlying. Grass grows rapidly and abundantly; trees are sparsely dotted over the boundless veldt, which forms an ideal cattle-raising country, and is populated principally by aboriginal natives. The ruling gradient on this section of the line is 1¼ per cent., uncompensated for curvature, of which latter the maximum is 6 degrees.

At Mafeking are situated the locomotive workshops and executive headquarters of the running staff, the railway settlement, consisting of 100 dwellings for married employees, and barracks for single men, forming a neat little village.

The recreation of the employees has not been overlooked, and a commodious institute, comprising theatre, billiard room, reading room, library, &c., is not the least important feature of the little village.

The town of Mafeking is situated to the east of the railway, and is the nearest point of railway communication to the Western Transvaal, with which a branch line connects, starting from Mafeking, entering the Transvaal at Buurman's Drift, and thence by way of Ottoshoop to Krugersdorp and Johannesburg.

Continuing the journey toward the Victoria Falls, the line passes from Cape Colony into the Bechuanaland Protectorate at a point 16 miles north of Mafeking. The country now becomes more hilly and more thickly wooded, and, after a few stiff climbs, drops away from 4,400 ft. to nearly 3,000 ft., continuing at this altitude for some 300 miles. These lower levels of the protectorate are sparsely populated, thickly wooded, and sandy; water is very difficult to obtain, the established supplies being a long distance apart, and frequently failing entirely. The principal waterways are the Mahalapyo, Lotsani, Macloutsi, Shashi, and Tati Rivers, dry for the major portion of the year, but running very strong during the summer rainy season.

Near Plumtree, and 419 miles north of Mafeking, the line enters Southern Rhodesia, and ascends tortuously to the higher altitude of 4,400 ft., at which Bulawayo is situated. On this section are more small bridges and culverts, and a greater percentage of curves than hitherto encountered. The ruling gradient is 1¼ per cent., with 4-degree curves. The country here is picturesque, green, and well wooded, the Matopos Hills, famous in war and as the last resting-place of the founder of Rhodesia, being visible from the train.

The territory traversed by the railway between Mafeking and Bulawayo forms the homes of many native tribes, and their primitive huts and habits of life may often be studied from the train. They dress grotesquely, own large herds of cattle, and exist on maize, sorghum, and millet, which grow well in the valleys. The only white settlement of any size is at Francistown, 364 miles north of Mafeking, where a mining and trading industry is carried on, and the headquarters of the Government of the Northern Protectorate situated.

At Westacre Junction, 17 miles south of Bulawayo, a small branch line has been laid, nine miles in length, and within easy distance of the "World's View," the last resting-place of the mortal remains of Cecil John Rhodes.

The Cape line enters Bulawayo from the west, and here the journey to the Zambesi may be broken or continued at will, there being a connecting train in waiting, while the town of Bulawayo, with its fine buildings and palatial hotels, affords every convenience for a brief or prolonged stay, combined with excursions to the Matopos Hills and many points of interest in its vicinity. Being situated at an altitude of 4,400 ft., the climate of Bulawayo is bracing and equable.

Bulawayo is fast becoming one of the most important railway towns of the African Continent, and, from its central position, lends itself as the future head-quarters of the Rhodesia Railways Administration. It forms the junction of the lines from Cape Town, &c., and the Matopos branch, which enter from the west, of the main line from Beira and Salisbury, and the Gwanda and Selukwe branches, which enter from the south-east, with the Zambesi line, which lies in a north-westerly direction.

Leaving Bulawayo by the last line, the profile of the country falls steadily to the Gwaai River, 89 miles from and 1,200 ft. lower than Bulawayo. From the Gwaai the line traverses more of the flat, sandy and thickly-wooded country, and here the line is perfectly straight for 71 miles From the end of this piece of straight road to the Wankie coalfield the line continues to fall between hills and through thick bush, until the low altitude of 2,400 ft. is reached. Over this section 4-degree curves and 1¼-per cent. gradients rule, but it was only on the last 50 miles that heavy cuttings and embankments were unavoidable.

Leaving Wankie, the journey to the Zambesi is continued over 6-degree curves and 2-per cent. gradients until the watershed of the Zambesi, some 12 or 13 miles from the river, is reached, and at this distance a great column of spray is distinctly visible. The railway station and commodious hotel are situated 282 miles from Bulawayo, and just to the south of the Falls. The magnificent and impressive sight of the vast volume of water falling precipitously 400 ft. is one which cannot fail to gain the traveller's admiration and awe. Just below this great cataract the gorge is spanned by a graceful bridge, 630 ft. long, with two short approaches and one main span of 500 ft., at a height of 480 ft. from the surface of the river, and adding considerably to the attractiveness of the scene. The handiwork of Nature and man is blended in a manner almost unique, and from this great triumph of engineering art and constructive ability a magnificent view of the 50,000,000 "horse-power-unharnessed" is afforded.

The sides of the chasm are formed of an igneous rock, hard in structure, reddish brown in appearance, and well covered with vegetation. Prior to the construction of the bridge, this rock had always been thought solid, but when the work of excavating the foundations for the abutments of the main arch was undertaken, it was discovered that the

"TRAIN-DE-LUXE" LEAVING BULAWAYO STATION

upper part of the south bank was composed of rock *débris* to a considerable depth. This unexpected circumstance not only caused much unforeseen labour and loss of time, but it necessitated the lowering of the level of the entire bridge by 20 ft. It is probable that the place where this *débris* lay was formerly the precipice over which the water fell previous to the time when the dividing barrier between it and the present fall was removed by the erosion of water.

The entire bridge, with the exception of the main bearings, weighs approximately 1,500 tons. When the live load (1,820 tons) is added to this, a vertical load of 3,320 tons has to be supported by the foundations, of which only about 280 tons is borne by the outer ends of the shore spans, the greater portion being carried by the four bearings of the principal span.

The bridge consists of three spans. The end span on the left bank of the river is 62 ft. 6 in., and that on the other bank 87 ft. 6 in. These spans are composed of braced girders of ordinary type, 12 ft. 6 in. deep, with horizontal upper and lower chords, and divided into square panels. The girders are fixed 20 ft. apart. Connected with the end posts of the central span they unite it with each bank of the river in a simple and direct manner. The deck is horizontal and is laid on the top chords throughout.

The central span is 500 ft. from centre to centre of bearings, with a rise of 90 ft. The curvature of the arched rib is parabolic. The panels, twenty in number, are 25 ft. in length. The depth of the girder at the crown is 15 ft., and at the abutment 105 ft. Each main girder stands in a plane at an inclination of 1 in 8 from the perpendicular. The width between the centres of the girders is 27 ft. 6 in. at the top and 53 ft. 9 in. at the springing level, and the width between the parapets is 30 ft.

The contract for this great bridge was finally secured by an English firm—the Cleveland Bridge and Engineering Company, of Darlington—and although everything possible was done to assist the contractors, the erection of the bridge was a matter of considerable difficulty. They were provided with free transport to the spot for all material for the bridge, houses were built for the workmen, and a powerful aerial cableway was provided for the transport across the hitherto impassable gorge of one half of the material for the construction of the bridge, which was designed so that it might be built out from both banks of the river simultaneously.

The cableway consisted of a steel wire rope 8·4 in. in circumference, with a breaking stress of 270 tons, and 830 ft. in length, suspended between two supports, one of which was vertical and of ordinary type, the tension of the cable being carried by guy ropes fastened in the rock. The other support was inclined and carried a weight of several tons equal to the working stress on the cable. As the conveyor moved across the gorge to the centre, this weight was lifted, but fell again as the conveyor moved over to the far side. The effect of this "compensating" arrangement was to make the power required for operating the conveyor more uniform throughout its travel. The conveyor, of the "Brothers" type, carried its own driving mechanism, operated by a crane motor of 20 b.h.p., and lifted a load of 10 tons at a speed of 20 ft. per min. and travelled with it at 300 ft. per min. The motor received current from a trolley wire crossing the gorge, the electric supply being obtained from a small generating plant sent out for this purpose. This plant consisted of a dynamo, running at 970 revs. per min., and generating 220 volts, driven by a portable engine of 14 h.p.

In effect, the principle of the apparatus is that of an overhead travelling crane in a workshop, but instead of running on a solid rail it runs on a wire rope; the driver sits in the travelling carriage and from there he controls the lifting, lowering and travelling movements. The obvious criticism against this proposition duly made its appearance. No man, it was alleged, could be induced for wages to occupy the driver's seat

and for months together travel all day long to and fro across that awful chasm. Though many troubles were encountered, the event proved that this was not one of them.

The conveyor successfully handled all the material required for the northern half of the bridge, and many thousands of tons of permanent way material required for the construction of the portion of the line north of the Zambesi.

Throughout the preparation of the design, the question of erection was considered to be of primary importance, and every detail was devised to simplify the procedure. The arrangement to erect each half of the main girders as a cantilever was not only essential in the circumstances, but was by far the easiest plan, scaffolding being both impossible and unnecessary. Little difference was required in the scantlings necessary for the arch to provide for the stresses set up by the cantilever.

This type of design made an efficient anchorage during erection a *sine qua non*. The strength of the attachment had therefore to be equal to the pull caused by the weight of the projecting bracket or cantilever, with a sufficient surplus for safety. The pull on the anchorage apparatus was estimated at 400 tons, and in the present case the means of attachment were provided by a series of steel wire ropes. These were secured to the top of each cantilever, and carried to a point some distance to the rear, where they entered a hole bored downwards in the solid rock, through it at right angles to the bridge, and up again on the other side, thus each wire formed a loop gripping the rock, with its free ends fixed to the cantilevers.

The most difficult part of the construction of the bridge was the erection of the end spans, but when once the tall end posts of the main span were erected, and the short spans were connected with them and the shore, affording a stable platform to start from, the work proceeded rapidly and smoothly.

The designing of the bridge was a work of many months in the office of the company's engineers, Sir Douglas Fox and partners and Sir Charles Metcalfe. The quality of the steel of which the structure was composed was strictly defined in the specification, and the material itself, which was rigidly inspected and tested, is capable of bearing an ultimate tensile strain of 30 tons to the square inch. As regards quality and accuracy of workmanship, it was stipulated that the principal members should be made to within one thirty-second of an inch of their calculated length. Before being shipped, every panel of the arch and the lateral bracing was put together in the contractor's works and fitted with perfect accuracy.

Owing to the spray from the Falls which descends upon the bridge during the wet season, the question of maintenance is of paramount importance, and it is an important feature of the design that every portion of the steelwork is accessible to the painter's brush. The painting can fortunately be very successfully carried out by natives. This is particularly satisfactory as, prior to the advent of the railway, there was not a native living within sixty miles of the Falls, owing to their superstitious dread of the locality, but now this has been overcome the proper preservation of the structure is assured.

From the river the railway rises and gradually disappears into the vast and unknown regions of Equatorial Africa.

The whole of the Vryburg-Zambesi construction was carried out under the direct supervision of Mr. S. F. Townsend, chief resident engineer of the Rhodesia Railways.

The great feat of bridging the Zambesi at the Victoria Falls was not allowed to interfere with the progress of railway construction and the line was gradually pushed on, on the north side of the river, at the same time that work on the bridge was being carried on. Permanent way and other materials were taken across the gorge by means of a cableway of the "Brothers" type.

The first section of the line, 94 miles in length, brought the railway to Kalomo, the capital of North Western Rhodesia. Construction of this section was very

rapid, owing to the absence of any engineering difficulty. The line rises gradually from the Zambesi and has been carried along the watershed of the country. From Kalomo the line has been continued to the Broken Hill Mine, a distance of 281 miles, which was reached on the 11th June, 1906, and was constructed at an average rate of a mile a day. On one occasion no less than 5¾ miles of track were laid in twelve hours, and it is believed that this constitutes a record in the history of rapid railway construction. The chief feature from the engineering point of view on this section of the line was the construction of the Kafue River Bridge. This bridge consists of thirteen spans, each 100 ft. long, and is to-day the longest bridge in existence in South Africa, just as the Victoria Falls Bridge is the highest.

The policy adopted in the construction of the line south of the Zambesi has also been pursued on the northern extensions. The track has been laid with 60 lb. rails and has been constructed as lightly and economically as is consistent with safety and efficiency, and brought up to the standard of the other sections of the railway.

This section taps a district exceedingly rich in copper, lead and zinc deposits, and a large traffic is expected from the conveyance of ore to the coast. The present terminus at Broken Hill is 2,017 miles north of Cape Town, and there only now remains a section 430 miles long to complete the connection with Kituta, with the southern end of Lake Tanganyika, where the Chartered Company's administration ends. A survey has already been made from the Broken Hill northwards to Bwana M'Kubwa, and there is no doubt that within the next few years this section will be made.

From this point onwards, however, Mr. Rhodes' scheme has had to be modified, as the nature of the country around the chain of lakes stretching from the Zambesi to the Nile became known. On the one hand Lake Tanganyika is hemmed in by steep mountains offering well-nigh insurmountable difficulties to railway construction, while on the other hand the lake itself offers a magnificent waterway of 400 miles in a direct line between the Cape and Cairo. It may be taken as granted therefore that this part of the journey will be made by water, and that passengers will be carried by steamboat from Kituta to Usambara, at the north end of the lake. From here to Lake Kivu is a distance of 90 miles, offering no serious obstacle to a railway beyond a rise in level of 2,000 ft. Lake Kivu is 60 miles in length, and this sheet of water is also surrounded by high and precipitous mountains, so that another break in the line will have to be made and the waterway utilised.

From Lake Kivu to the Albert Edward Lake is another 60 miles, with a further rise of 2,000 ft. to the highest point on the whole route. The country to the east of the Albert Edward Lake is so flat that it may be unnecessary to use this fine stretch of water (75 miles in length), as a railway could be built from Lake Kivu, through a rich, healthy and densely populated country, pass the Albert Edward Lake, and down the Semliki Valley to the southern shore of the Albert Lake, a distance of 220 miles. The Semliki Valley is in Congo Territory, but this is believed to be the obvious route for the railway, with no engineering difficulty but a drop of 1,500 ft. before reaching the level of the Albert Lake, while the alternative route through British territory would involve a climb of 2,000 ft. and a sudden descent of 3,000 ft. Once the Albert Lake is reached there is a navigable waterway right away to the Mediterranean, by way of the White Nile, save for a stretch between Dufile and Rejaf, where the river is broken by about 100 miles of rapids, which would have to be spanned by another length of railway. An alternative route is possible *via* Abyssinia, the Emperor of Abyssinia, under the frontier agreement of May, 1902, having agreed to allow the construction of a railway through Abyssinian territory from the Soudan to

Uganda. However, now that the dense tangled mass of vegetation known as "sudd," which obstructed the river between Fashoda and Lake Albert, has been broken up, the Nile route will probably be preferred to another. Since the commencement of 1904 a regular service of steamers has been plying between Rejaf and Khartoum, a distance of 1,000 miles, and Khartoum is now connected with Cairo by railway, except for the short stretch of the Nile between Wady Halfa and Assuam.

Thus, when once the railway reaches the southern end of Lake Tanganyika, the construction of a further 470 miles of railway is all that will be necessary to render steam communication by combined rail and waterway between the Cape and Cairo an accomplished fact. When these 470 miles of railway are constructed, Rhodes' splendid dream will have been realised, if not in its entirety, at least as far as the object which he had in view; for it is evident from what he wrote during his life that it was not as a "through line" that the Cape to Cairo Railway appealed to his imagination, but as a feeder line to branch railways, running east and west, so that the breaking bulk necessitated by the changes from land to water carriage is no drawback to the general utility of the scheme. Two such branch lines are already in existence—from Beira to Bulawayo, *via* Salisbury, and from Mombasa to the Victoria Nyanza, and others are projected both on the east side in German East Africa and on the west side in the Congo Free State. A line about 243 miles in length is also in course of construction between the southern end of Lake Nyasa and M'Tombi on the Shire River, whence there is a steamer service to the sea *via* the Zambesi.

THE FIRST TRAIN ON THE ZAMBESI BRIDGE.

RAILWAY ENGINEERING NOTES.

0-6-4 Type Tank Locomotive: Midland Railway.

The accompanying illustration is that of a new type of tank engine recently constructed at the Midland Railway Co.'s works at Derby, to the design of Mr. R. M. Deeley, M.Inst.C.E., locomotive superintendent, to whom we are indebted for the photograph and following information.

The design, while conforming as closely as possible to the company's standard practice, marks a departure in wheel arrangement, which, as will be seen, comprises a six-coupled and trailing bogie arrangement. Further, in conformity with recent tank engine developments, the design represents an advance both as regards proportions and power over the company's existing tank locomotives.

The first feature that may be noticed is the large rear tank, which connects by large equilibrium passages giving 100 sq. in. clear water connection, with the front tanks, which, as will be seen, extend to the front of the smoke-box, thus affording a total water-carrying capacity of 2,250 galls.

A water pick-up apparatus is also fitted, enabling the engine to undertake runs of a length much greater than is involved in ordinary suburban train work. This gear is designed to work when the engine is running either backwards or forwards, the scoops, which operate between the rear pair of coupled and leading pair of bogie wheels, being raised or lowered by hand gear. The water is taken up by a Y pipe to the rear tank, a flap valve closing the mouth that is not in use.

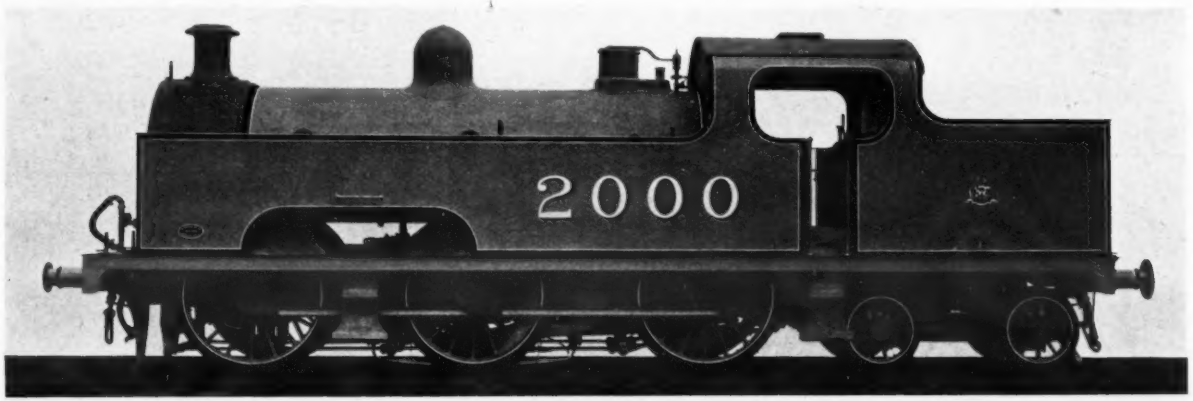
The coal capacity of the bunker is 3½ tons, and this is obtained by giving the bunker a greater length than is customary to obviate the objectionable practice of heaping up coal to cab-roof level, thus obscuring the outlook of the men when running bunker forwards. This object is further assisted by the non-provision of railings on the bunker.

The boiler is of the Midland standard type, made up of two lengths with a telescopic joint, and has a round top fire-box shell.

The frames are of 1-in. steel plate, also made up in two lengths, the rear sections passing within and being separated from the front length by a packing piece, thus reducing the end dimensions by 3 in.

The valve motion, which is practically the same as that of the company's standard goods engines, is of the "Stephenson" link pattern operating balanced slide valves, which work between the cylinders, the latter being bolted to the insides of the frames. They are 18½ in. by 26 in. stroke, and are set at an inclination of 1 in 8½ in. Special attention has been given to rendering the movement of the engine round curves easy. The small ends of the connecting rods are fitted with a ball and socket arrangement, to allow for side play of the driving axle, and the side rods are provided with ball and socket bushes at the pin joint connection in front of the driving wheel crank pin. The leading axle has the "Cartuzzie" axle boxes in a modified form, allowing of 1¼ in. side play. The bogie at the trailing end has a total side play of 5½ in. It is built up of plate frames, &c., and has inverted laminated springs.

The equipment includes automatic



0-6-4 TYPE TANK LOCOMOTIVE, MIDLAND RAILWAY.

vacuum and steam brake, also hand brake, and steam heating apparatus.

Steam sanding gear is fitted, sand being delivered under the tread of the driving wheels on both sides. Lubrication is effectively performed by sight-feed lubricators to each axle-box, sight-feed displacement to the cylinders, and special suction lubricators for the slide valves.

The following are the leading particulars of the engine :—

Cylinders: diameter	18½ in.
„ stroke	26 in.
Coupled wheels: diameter	5 ft. 7 in.
Bogie wheels: diameter	3 ft. 1 in.
Boiler, barrel diameter	4 ft. 9⅛ in.
„ „ length	10 ft. 5⅛ in.
„ length between tube plates ...	10 ft. 10⅝ in.
Tubes (copper), number	242.
„ external diameter	1¾ in.
Firebox shell, length	7 ft.
„ „ width at bottom	4 ft. 0½ in.
Heating surface, fire-box	125 sq. ft.
„ „ tubes	1,206 sq. ft.
Total	1,331 sq. ft.
Grate area	21·1 sq. ft.
Working pressure	175 lbs.
Tractive power	0·0593 ton per lb. of steam pressure.
Adhesive load	52 tons
	13 cwt. 1 qr.
Combined tank capacity	2250 gall.
Coal capacity	3½ tons.
Total wheel-base	29 ft.
Total length over buffers	40 ft. 4½ in.
Weight of engine in working order ...	72 tons
	8 cwt. 1 qr.

Superheater Tests.

A number of tests have been recently carried out with a "Cole" superheater fitted to the locomotive at the Purdue University, the results obtained being very instructive. The superheater itself consists of a series of return tubes extending inside certain flues which make up a portion of the direct heating surface.

To make room for the superheater the upper central portion of the usual flue space is taken by sixteen 5 in. flues, which are reduced to a diameter of 4 in. for 7 in. of their length at the fire-box end, and increased to a diameter of $5\frac{1}{16}$ in. at the front tube sheet. They have a length between flue sheets of 138 in. In each of these sixteen flues there is an upper and a lower line of superheating tubes. Each line extends from a steam pipe header in the smoke-box back into its flue to a point near the back tube sheet, where it meets and is screwed into a return pipe fitting of special design. From the second of the two openings in this fitting, a similar pipe extends forward through the flue and into the smoke-box to a second header, from which branch pipes lead to the cylinders. Altogether there are thirty-two of these loops. In thirteen of the flues, the lower loops are $116\frac{3}{8}$ in. long, extending into the flue within 2 ft. 5 in. of the back tube sheet. In the other three flues, the loops are respectively 3 ft., 2 ft. and 1 ft. shorter than the normal.

The results, which are taken from a paper read before the American Institute of Mechanical Engineers, show that the degree of superheat in the steam delivered to the cylinders is largely affected by the rate of evaporation. Thus Fig. 1 shows that as the evaporation per sq. ft. of heating surface per hour is increased from 7 lbs. to 15 lbs., the degree of superheat rises from 127° to 188° F., due, doubtless, to the fact that the superheating surface, as compared with the direct heating surface, absorbs a greater portion of the total heat as the rate of evaporation

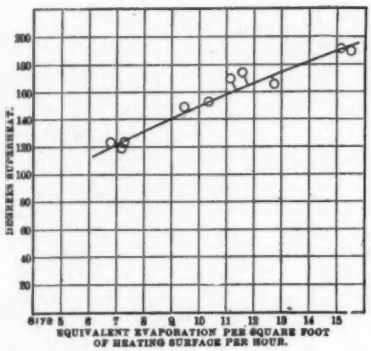


FIG. 1.

increases. Each pound of steam delivered received from the direct heating surface approximately 1,160 B.T.U., and from the superheating surface from 70 to 104 B.T.U., depending upon the rate of power at which the boiler was worked.

Fig. 2 shows the percentage of total heat taken up by the water and steam which is absorbed by the superheater, plotted in terms of smoke-box temperature. It will be seen that as the temperature of the smoke-box changes from 600° F. to 800° F., the heat absorbed by the superheater rises from

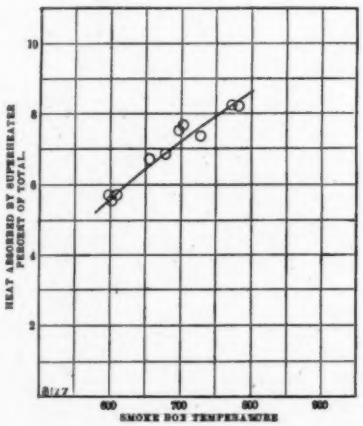


FIG. 2.

5·6 per cent. to 8·5 per cent. of the total taken up by the water and steam.

The amount of superheating was also found to increase rapidly as the loop is increased in length, this resulting from the fact that each increment in the length of the loop carries the superheating element nearer the fire-box, and serves to increase the average temperature to which the whole loop is exposed.

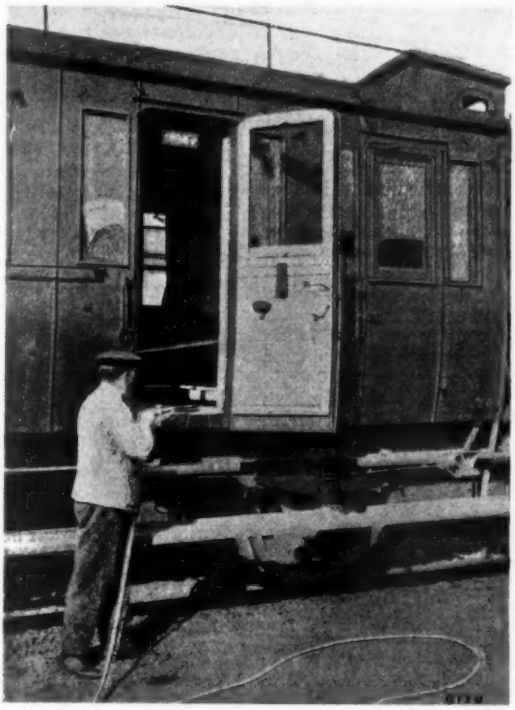
With regard to cylinder performance, under normal conditions of running with saturated steam, the consumption was from 24 to 27 lbs. of steam per i.h.p.; when fitted with a superheater and running under the same conditions the consumption for substantially the same locomotive dropped to from 20 to 22 lbs. per i.h.p.—a difference of about 17 per cent.

A New Carriage-Cleaning System.

A system of cleaning in which the combined effects of suction and pressure of compressed air are utilised has recently been introduced by Messrs. Borsig, of Berlin, in connection with railway carriages. The action of the apparatus is, according to the *Indian and Eastern Engineer*, based on the following principle:—

The mouthpiece of the apparatus terminates in two tubes, one of which serves to supply compressed air, and the other to draw the dust away. Both of the tubes are rigidly connected together, one end of either being coupled to a corresponding length of caoutchouc tubing.

Part of the compressed air issues in fine jets from the blower, enters the tissue, and loosens and expels the dust there deposited. The other part of the compressed air, owing to the nozzle effect, produces a vacuum, drawing off the raised dust, which, through a short piece of tubing, is thrown into a handy transportable filter, there to be precipitated, while the air escapes in a cleaned condition.



COMPRESSED AIR CLEANING SYSTEM ON A GERMAN RAILWAY.

A motor-driven compressor supplies air to a kettle which serves for compensation in the case of fluctuations in the consumption of air. Thence the compressed air arrives at the apparatus through an intermediary conduit and the feeding tube. The discharging tubes and filter are further parts of the apparatus.

Though the dust is loosened and raised most energetically by the compressed air issuing from the edge of the blower, it is prevented from escaping into the surrounding air by being drawn by the suction effort into the opening of the blower.

The apparatus can also be arranged for the pressure or suction effect to be used separately whenever required—an advantage in the case of very loose dust.

The plant used for cleaning according to the Borsig system is simple, and comprises a special or ordinary compressor of substantial and simple design, which requires little superintendence, steam engines or electro-motors or any other kind of prime mover being used for the operation.

Balanced Slide Valve for High Pressures.

The rapid rise in steam pressures have led to modifications in the design of the ordinary D slide valve, and to a growing extent to the introduction of the piston valve. Some remarks concerning the latter will be found in another note; it is to an interesting design of a balanced slide valve that it is here desired to call attention.

The main valve consists of three principal parts; the valve proper, the balance plate, and the pressure plate.

The valve has two faces, one operating on the valve seat on the cylinder, and the other against the face of the balance plate. Both faces are the same, and that of the balance plate against which the valve operates is a duplicate of the cylinder valve seat. The walls of the valve are provided with ports *A E*, which pass from face to face of the valve.

The balance plate, Fig. 2, contains the balancing cones *M C* and *P C*, and two centering ring grooves which register with like grooves in the pressure plate above. It also supplies the means for double admission and double exhaust openings by admitting and exhausting steam at the face of the plate at top of valve simultaneously with admission and exhaust at valve face and cylinder valve seat.

The face of the balance plate, as before stated, forms a second valve seat, being held by means of the centering rings *C R* in exact alignment with the valve seat proper. The back or opposite side of the balance plate contains a main

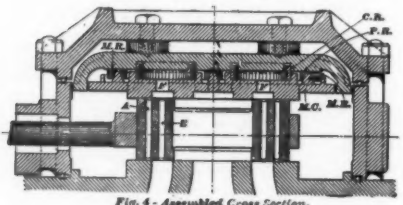


Fig. 4 - Assembled Cross Section.

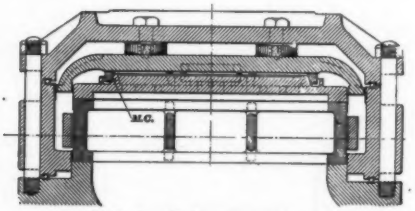


Fig. 5 - Assembled Longitudinal Section.

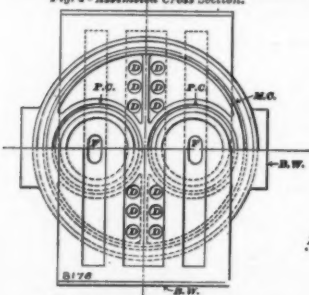
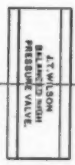


Fig. 2 - Plan of Balance Plate. Half Face. Half Back.



End View of Valve.

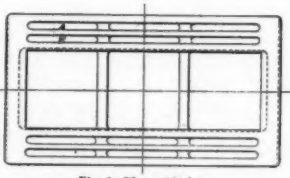


Fig. 1 - Plan of Valve.

cone *M C* and two small cones *P C* on the interior of the main cone, and on which the packing rings are placed, which forms the balancing feature of the valve, and the centering ring cones. The balance plate is provided with wings *B W*, which fit $\frac{1}{16}$ in. loose into the wings of the pressure plate above, preventing excessive movement of the plate. Taper or bevelled packing rings set on the cones form joints against the pressure plate.

The pressure plate, which can be made as a part of or separate from the chest cover, has in its face two grooves which register with corresponding grooves in the balance plate below. Into these two centering rings *C R* are placed.

The tops of the cones *M C* are $\frac{1}{8}$-in. from the face of the pressure plate, allowing the balance plate to lift $\frac{1}{8}$-in. off from the valve, which affords relief to the cylinder while engine is drifting and for the relief of water from the cylinder. The main balancing ring *M R* is made the proper diameter to balance the valve as much as possible while in its central (or heaviest) position, there being just sufficient area left on to insure the balance plate being held steam-tight on the valve. The interior of the main ring is open to the atmosphere through the holes *D*, which lead to the exhaust cavity of the valve.

On the opening of a steam port the port pressure has free access to both sides of the valve by reason of the passages *A E* through the valve to the port in the face of the balance plate which corresponds with the cylinder port, consequently the pressure in the port has no effect upon the valve, as it acts on both sides of the valve face in equal area and pressure. But the pressure in the port of the balance plate would lift the plate off from its seat on the valve if it were not also equalised, therefore a port ring *P R* is placed over each port on the top of the balance plate and is open to the port through passage *F*, so that a pressure equal to that in the steam port is always on both sides of the balance plate. Communication from the cylinder port, through the valve and through the balance plate to the interior of the port ring *P R* cannot be shut off at any time, but is maintained throughout the travel of the valve.

There is another position of the valve in which it is subjected to an upward pressure, tending to lift it from its seat, that position being at the over-travel of the valve face over the valve seat. It will be readily understood, however, that the top face or back of the valve travels from under the seat of the balance plate to exactly the same extent that it over-travels the cylinder seat, and pressure is therefore equal on both sides of that portion of the valve that is over the seat at any point of travel.

With the main ring balancing the valve fully in its central position, the port ring balancing the port pressure, and over-travel of the valve on its seat being equalised by equal exposure at top and bottom, it will be clear that the valve is fully balanced in all positions of the stroke.

Locomotive Piston Valves.

The piston valve is daily coming into more general use as its errors are corrected and prejudices overcome. On some American trunk lines it has practically superseded the slide valve, and it seems idle to longer deny it at least equal rank with its older competitor.

In the course of an interesting article,* which traces the earliest applications of the piston valve to locomotives to present day uses, the advantages and disadvantages of this type of valve are well summarised.

Firstly, there is perfect balance, that is, when properly constructed, with just enough area of ring acted upon by pressure to make it properly steam-tight, without unnecessary friction; a simpler, lighter and cheaper cylinder casting, a wearing face separate from the cylinder casting which can be

* H. R. Stafford in the *American Engineer and Railroad Journal.*

cheaply renewed; ports in cylinders readily made very straight and direct; and its adaptability to any design of valve gear, since it can be placed above the cylinder, between the frame rails, or in any other position with equal facility. Its general tightness to steam is conceded by engineers on both sides of the water to be about equal to a good slide valve. Again, it practically does away with one set of metallic packing, as almost any form of hemp packing is sufficient to hold exhaust pressure, assuming the valve to be of the inside admission type.

On the other hand, it is accused of many shortcomings, most of which can be overcome, and some of which have already been eliminated in special designs in use to-day.

Many motive power men are of the opinion that an engine equipped with piston valves cannot develop the speed of a slide valve engine, both being otherwise of the same design. The fact that some of the very fastest trains are pulled by piston valve engines would seem to refute this argument; but as many of the older engines had valves entirely too small, these opinions may have been based on such poorly designed engines. Such an opinion might have been formed by comparison with outside admission piston valve engines. This is also unfair, as the outside admission piston valve has a proverbially poor exhaust. Inside admission has become the rule, and special care is at present taken to shape the steam chest covers to direct and to offer the least possible resistance to the exhaust.

The above table gives recommended diameters of valves for different bores, it being assumed that the sizes given are large enough for the longest stroke commonly used with this bore. The table also shows the net length of the port (with bridges deducted) for each diameter, and the corresponding length of slide valve port in common use.

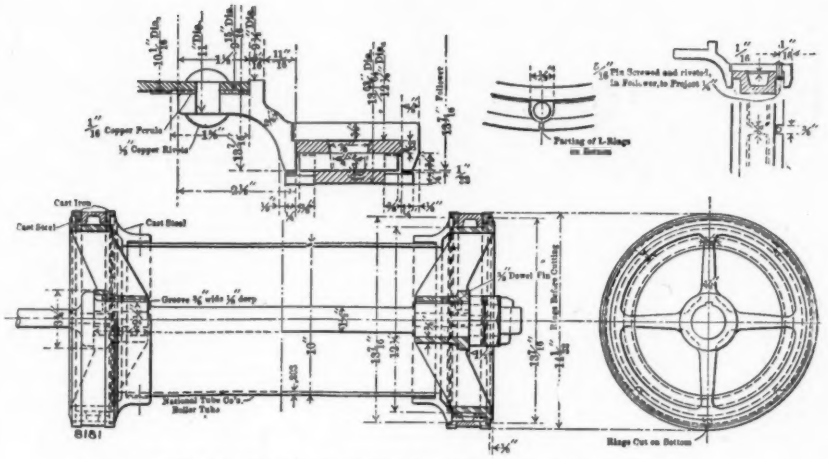
Another objection to the piston valve is the fancied increase of cylinder clearance. This, while it may be that clearance is larger in many cases than on a similar slide valve cylinder, is by no means necessary. It can usually be kept between 6 and 8 per cent., except on very short-stroke engines, and this is low enough with ordinary valve gear.

Diameter of Cylinder.	Diameter of Piston Valve.	Net Length of Piston Valve Port.	Length of Slide Valve Port.
17	10	25	16
18	11	26½	16
19	11	26½	18
20	12	30½	18
21	12	30½	20
22	12	30½	20
23	14	34	20

The greatest disadvantage under which the piston valve labours is its inability to relieve excess pressure in the cylinder port by lifting, after the manner of the slide valve. This renders some sort of a cylinder head relief valve imperative. For this purpose the ordinary spring pop valve is generally used, and although many objections are raised to this device, it has not been proved that pop valves of ample size, properly designed and taken care of, will not eliminate cylinder head breakage, except in cases of deliberate attempt to use cylinders and pistons as hydraulic rams. Various types of by-pass valves are also used with success, in which the pressure in the chest is made to serve in place of the spring in a manner analogous to the slide valve.

Plug Valves.

To use a solid, incompressable valve, of perfectly circular section and incapable of accommodating itself to the irregularities of the bushing, as, for example, the plug valve used in continental practice, requires considerable modification in the bushing. In the first place it must be able to expand and contract independently of the cylinder casting; at the same time it must be held in true central position, with the steam edges of the ports always in the same relation to each other and to the cylinder itself. Moreover, at least two steam-tight



PISTON VALVE USED ON THE COLE BALANCED COMPOUND LOCOMOTIVE.

joints must be made on this bushing with the cylinder port walls. The valve must be of such section that it will not expand more quickly than the bushing when it suddenly comes in contact with the entering steam, and should cool at least as quickly when steam is shut off.

These conditions, together with a perfect fit between the valve and bushing, are said to have been met by the "Schmidt" valve, used in connection with the "Schmidt" superheater. This system employs for the purpose a double bushing, between the inner and outer shells of which steam has free access, joints with the port walls being made with copper gaskets. The valve is of small diameter, with a double exhaust feature. The system has been tried in America without much success.

The nearest thing to the plug valve in successful service is the "Semi-Plug" valve.*

As a type of the modern valve, showing the lightest possible construction combined with great strength, attention is called to the above illustration, which is the valve used both on the high and low pressure cylinders of the "Cole" balanced compound. In this the body or spool consists of seamless steel tubing, with light cast steel ends riveted on.

*ENGINEERING REVIEW, Vol. XVI., pp. 189 to 190.

PAPERS READ AT THE ENGINEERING CONFERENCE; INSTITUTION OF CIVIL ENGINEERS.

Machine-Tool Design as affected by the Use of High-Speed Cutting Tools.

By Prof. JOHN THOMAS NICOLSON, D.Sc. M.Inst.C.E.

THE design of the lathe, the most important of all machine-tools, has been greatly modified by the introduction of the high-heat steels. Much greater power, strength, and rigidity are now necessary, and many faults of construction, always existing, have been laid bare by the severe tests imposed by the use of the new steel.

The power required depends upon the area of the cut, the force upon the tool, and the speed with which the cut is taken.

The first factor depends upon the size and nature of the work. In repetition work, forging can be done closely to size, and only fine cuts need be taken. This appears to be the reason why American lathes are, on the whole, lighter than those of British design. In general engineering work, however, lathes which can take heavy roughing cuts are necessary, for it is cheaper to forge only approximately to size and afterwards remove the excess material in the lathe, when a small number of pieces of any one kind are required. The amount which may nowadays be economically left on a forging is greater than it was, because it is less costly to produce a ton of shavings with high-heat steel than with low heat; not because the work required to machine off the ton is any less, but because the on-cost charge is smaller. This remark suggests that the "standard cut," by which is meant the size of the shaving which the lathe is designed to remove (on machinery steel), might reasonably be fixed at a higher value now than formerly. In the comparisons which follow this has not been done, however, but a cut having a depth equal to one-fortieth of the height of centres and a traverse feed one-quarter of this have been assumed: a result based on data collected from practice.

With regard to the second factor number two, it is now known that the vertical pressure exerted on the point of a tool of ordinary shape is 100 tons per sq. in. for soft steel, and about 80 tons per sq. in. for cast iron. These figures appear not to vary much with either the area of the cut or its shape, and to be, to a first approximation, independent of the speed. The cutting force is thus the same whether carbon or high-heat steel is being used, and, the standard cut having been assumed the same for both, the power required will depend only on the speed of cutting.

This leads us to the third factor, the cutting speed. As will appear from an inspection of the accompanying table, the high-heat steel has increased the speed about threefold for the heavy and moderate cuts, and about five to seven-fold for light cuts.

The power required is therefore from three- to seven-fold as great for high- as for low-heat steel. See Table on page 39.

Heavy cuts are more economical than light, if both are taken at their appropriate speeds, because:—1. The high-heat steel will cut a greater weight per unit of time, without damage. 2. The gross power is less per unit of weight machined.

The Highest and Lowest Spindle-Speeds, and their Ratio.—These data are fundamental to the design of the fast headstock; and the

CUTTING SPEEDS FOR HIGH- AND LOW-HEAT STEELS COMPARED.

Depth of Cut.	Traverse Feed.	Area of Cut.	Speed with Carbon Steel	Speed with High-heat Steel
In.	In.	Sq. in.	Feet per minute.	Feet per minute.
$\frac{1}{4}$	$\frac{1}{10}$	0·005	20	150
$\frac{1}{2}$	$\frac{1}{10}$	0·01	20	110
$\frac{1}{2}$	$\frac{1}{16}$	0·05	16	50
1	$\frac{1}{16}$	0·10	13	40
1	$\frac{1}{8}$	0·20	10	30

POWER REQUIRED FOR LATHES WITH HIGH- AND LOW-HEAT STEELS COMPARED.

Height of Centres.	6 ins.	12 ins.	18 ins.	36 ins.	60 ins.
	H.p.	H.p.	H.p.	H.p.	H.p.
Power for carbon steel	1	3¼	6½	16	25
Power for high-heat steel	7	13	19	50	75

following figures, rationally deduced, have been confirmed by practice:—

Height of Centres.		6 ins.	12 ins.	18 ins.	36 ins.	60 ins	
Spindle speeds for carbon-steel lathes	Greatest ...	300	150	102	50	30	Ratio
	Least ...	6 50	3 50	1·7 60	0·5 100	0·16 180	
Spindle speeds for high-heat-steel lathes ..	Greatest ...	600	300	200	100	60	Ratio
	Least ...	60 10	10 30	4 50	1 100	0·3 120	

From this table it is seen that the highest spindle-speed has been doubled throughout, whilst the lowest spindle-speed has been increased tenfold for the smaller, and about twofold for the larger sizes. Thus the ratio of the greatest to the least is not so great as it was for the carbon-steel lathes. This means that, as the number of different spindle-speeds to be provided depends on that ratio, so many speeds and gears are not required for high-speed lathes as were necessary to secure a proper subdivision in a case of carbon-steel lathes; this being more especially true for the smaller sizes.

The Belt-Drive.—To enable them to transmit the great powers now required, much higher belt-speeds have become necessary. In the old lathes, which always had their cones mounted on the spindle, the belt-speed was limited, by the necessity of connecting that cone to the spindle for direct driving, to between 600 and 1,200 ft. per min. This bad practice has now been abandoned by most of the good makers, the cone being placed on a back-shaft and geared down to the spindle by spur and pinion. In this way speeds through the air of 2,000 or 3,000 ft. per min. can easily be obtained, and unduly wide belts avoided. The efficiency of the belt-drive is also improved by using large pulleys running at moderate speeds, rather than small pulleys running at very high rates of revolution.

In obtaining the required number of different spindle-speeds it has been found to be better, from the point of view of a good belt-drive, to secure them by increasing the number of back-gears rather than by adding to the number of the cone-steps or of the counter-shaft speeds. The former method is naturally accompanied by a larger first cost; but the ultimate economy is entirely in the purchaser's favour.

Gears.—Tooth-durability has now to receive more attention than formerly. All wheels must be machine-cut, and the proportion of width to pitch very much increased. These broad wheels with finely pitched teeth are conducive to smooth running. Small arcs of approach and enlarged arcs of recess should also be used to secure durability or reduce wear.

Spindles and their Bearings.—There seems at first to have been a tendency to unduly increase the diameters of the front bearings of spindles for high-speed lathes. The torques are, however, no greater than before, and as the power is—at all events, for all but the smaller sizes—transmitted through the face-plate and not through the spindle, the reasons for the large increases of diameter to be found in practice is not very obvious. Increased rigidity is, no doubt, required to withstand the shocks, which are greater at higher speeds; but, in the author's opinion, lack of rigidity has been frequently due to elaborate and defective arrangements for adjustment in the main bearings. The adoption of solid bush-bearings, without any means of

adjustment whatever, but fitted with forced lubrication to prevent metal-to-metal contact at the lower speeds, and so altogether to avoid wear, appears to offer a solution of the problem which will enable spindles of smaller diameters and bearings of about half their present length to be used.

Beds and Saddles.—The greater vibration set up at high speeds of cutting by reason of the greater liability to resonance, necessitates stiffer beds than before. The time-honoured double H section of bed will ultimately have to be abandoned, and a bed of box or circular section substituted for it. The discrepancy between the strengths of the old-fashioned and the proposed sections, whether for resisting, bending, or torsion, is so great as to render the retention of the old design simply a ludicrous adherence to preconceived notions. Saddles have probably always been rather wabbly; but the high-heat steel has effectually laid bare their weaknesses.

Loose Headstocks.—For high-speed turning, the loose headstock needs to be very firmly bolted down at its four corners, and not at the middle. From this point of view it is bad practice to do taper turning by setting over the head. The increased number of joints and the position of the work between centres are against heavy cutting with success.

Feeding Mechanism.—All the feed-motions should now be fitted with inter-locking devices, and the feed should have a safety throw-out. The high speeds now used do not give the operator any chance of remedying mistakes. Any increase of the number of feed-changes above four, or at most six, is superfluous, and is a positive disadvantage, if the screw-cutting feed is taken through these gears.

Precision Grinding.

By H. DARBYSHIRE.

In this note I propose to deal briefly with the finishing of detail parts of machinery by means of abrasive wheels, both as regards precision of dimension and quality of surface finish. Speaking comparatively, the gratifying advantages that may be obtained from the use of high-speed steel are limited to a certain point, that point being where a fractional quantity of material must be left and extreme care exercised in arriving at the precise dimensions. For this final finishing I claim that the grinding-machine is the most rapid and economical tool to use, for the following reasons: it removes this fractional amount of material in the shortest comparative time; it arrives at the desired dimensions by a series of rapid and minute chips which cover the whole surface repeatedly and whose depth is under perfect control; any variation in its shower of sparks is instant and visible evidence of its change of form either through distortion or accident; and finally, it allows of the actual surface finishing being the last operation, thereby removing all those errors and distortions which are a result of keyways or other reductions. To those who are not conversant with the more modern development of the grinding-machine the first of these reasons may appear an exaggeration, but an inquiry into what is being done in the matter at the present time will only serve to substantiate the statement. For the correcting of hardened work it has long been considered a necessary part of the engineer's equipment, but its use for general finishing purposes has been, and is still, considered by many to be indulging in a luxury. The earlier machines were so limited in power and capacity that they formed merely a substitute for the file and emery-cloth, yet the superior quality of work they produced was in itself a recommendation of their use where more precise results were desirable or necessary. Their limited power and capacity necessitated the previous machining being done to within fine limits and with highly skilled labour, whereas the more modern machine, with its ready adaptability to removing comparatively more material in a given time, obviates the necessity of this close machining.

As instances of the amount of stock which may be removed by a modern grinding-machine I may quote the following examples of work done personally: Several cast-steel bars, 10 ft. in length and 48 mm. in diameter, were reduced to 46 mm. in an average time of 75 min., the greatest variation in diameter being 0.01 mm. A chilled-iron roll, 4 ft. long and 17 in. in diameter, was reduced $\frac{1}{16}$ in. diameter in 7 hours. A cast-iron roll 4 ft. by $6\frac{1}{8}$ in. was reduced $\frac{1}{16}$ in. diameter in 25 min., the greatest variation being 0·0005 in. These examples will convey some idea of the amount of material which may be removed in a given time by a grinding-wheel, and in the first two examples it was found more economical to grind outright from the rough black bar and casting than to turn and grind. I find the leaving of a grinding allowance of 0.015 in. to 0·030 in. on a

diameter to be the most economical for general work in a modern machine. These broad limits allow the previous machine-man to use coarse feeds and work rapidly. In order to keep within these limits rough tolerance-gauges are desirable, for if the maximum amount given be exceeded, waste of both grinder's time and abrasive material must ensue. The fact that a ground surface is superior to that produced by a file or water-cut is indisputable, and the rapid manner in which a fixed dimension may be obtained is a further recommendation; that the result is effected by a series of minute chips with a visible index of their depth is another point in its favour. In order to start a finishing cut in the lathe and control its size, the length of its traverse requires a sense of touch which may have taken years to attain; to obtain a similar result but a better surface in the grinding-machine is an easier matter, because another sense is enlisted, and the work is simplified. Given a few days' practice with a grinding-machine an operator can judge to 0·001 in. the depth of the cut he is taking, by the shower of sparks displayed. In actual practice, where accurate results are necessary, the following points must receive attention. The first in importance is that there must be an abundant supply of water delivered at the grinding-point to ensure the work being kept at an equable temperature. Hard bonded wheels should be avoided, as they do not cut freely, and may well be compared to a dull milling-cutter; they are mostly chosen through mistaken ideas of economy, but a little reasoning will prove the fallacy of this.

A grinding-wheel may well be likened to a milling-cutter, the bond of the wheel being, as it were, the spaces between the cutting teeth. While we are grinding we must be making spaces between these cutting teeth automatically, *i.e.* the bond must be friable enough to crumble away and allow the grit to penetrate the work to its maximum cutting depth. The degree of this friability of grade of the wheel has some relation to the texture and shape of material worked upon, and is governed by certain and easily understood laws.

Where a high degree of surface finish is required for appearance, only the grinding-machine is superior to hand-labour, for various reasons; it is more rapidly done, and leaves a surface more uniform and pleasing to the eye. This latter recommendation may seem a trivial one if we fail to remember that this method of finishing secures the most accurate results; it yields cylindrical work which is both truly round and concentric with the centre points on which it is held, and this is always an advantage. Again, in the finishing of plane surfaces the easiest method of holding the work to the machine-table is that which will give the most precise results; thus a slide or similar body would be outwardly finished by clamping its scraped and finished ways to packings ground in position. This ensures absolute truth of outer alignment, which would be of great value to the operator of the future built-up machine, and its beauty of finish would probably be a means of ensuring his care that its accurate condition be maintained. The great advance that has been made in grinding practice recently has been mostly in work of cylindrical form, and for this purpose its claims to attention are undeniable. Personally I see no reason why the same advantages cannot be obtained in the grinding of plane surfaces with a suitably designed machine. My opportunities of experience in this direction have been somewhat limited, but have served to convince me that many advantages would be gained by those who choose to take up the matter thoroughly.

The Use of Pneumatic Tools in Workshops.

By C. P. WHITCOMBE, M.Inst.C.E.

IT may perhaps be difficult for those now concerned in the everyday use of pneumatic tools, to realise that only about ten years have elapsed since portable pneumatic tools of a suitable design for general use in workshops became readily available in this country, the tools specially referred to being the hammer—for chipping, caulking and riveting, and the drill—for boring, tapping, rimering and like purposes. Previously, high-pressure air had been occasionally employed in workshops, but the machines utilised were of a class distinctly different from the hand-tools which have in recent years won their way to the front.

It may be assumed that the distinctive characteristics of the designs of pneumatic hammers and drills which have established their position are fairly well known; no radical changes appear to have been effected

during the past few years, but the efforts of designers and manufacturers have been directed, with a considerable measure of success, to improving the construction, economising the air-consumption and facilitating the operating.

From actual results the following comparisons of speeds of out-turn as compared with hand-work have been compiled; it is not claimed that these speeds are applicable to all classes of work, but that they can be generally attained and sometimes even exceeded:—

Description of Work.	Speeds. By Hand.	By Pneumatic Tool.
Heavy chipping ..	1	2 to 4
Caulking ..	1	3 ,, 4
Drilling	1	3 ,, 4
Rimering	1	4 ,, 6
Riveting .. .	1 (3 men)	1½ ,, 2½ (2 men).

The economical results achieved, so far as piece-work rates alone are concerned, are not nearly proportionate to the higher of the speeds enumerated above, but the reduced rates which have formed the subject of agreement between employers and employed, enable the latter to earn higher wages in a given time, and the increased rapidity of out-turn constitutes an important item for the employers' consideration when comparing results with hand-work. The following figures show, approximately, the reductions in piece-work rates effected by the use of pneumatic tools in the United Kingdom:—

Description of Work.	Percentage off Hand-Labour Rates.
Chipping...	35 to 50
Caulking...	35 ,, 55
Drilling	40 ,, 60
Rimering	50 ,, 75
Riveting	30 ,, 50

Figures recently prepared by a leading firm for their own information showed that a weekly saving of more than £2 was being effected in wages for every £1 of running cost of the pneumatic plant, the latter including interest on capital outlay, depreciation, power-charges, maintenance and repairs. The number of tools owned by the firm concerned exceeds eighty, and their compressing plant has a capacity of 1,500 cubic feet of free air per minute.

Reductions in piece-work rates in Germany are reported to vary as follows:—

Description of Work.	Percentage off Hand Labour Rates
Chipping and caulking	35 to 65
Drilling	50 ,, 80
Riveting	35 ,, 60

Reciprocating Air-Compressors.

By W. REAVELL.

I PROPOSE in this note to deal with the features which are necessary to obtain high efficiency in a reciprocating air-compressor. With the exception of low-pressure unjacketed machines, such as blowing-engines, the observations are applicable to all compressors within the limits of pressure ordinarily met with.

The losses to which an air-compressor is subject may be divided into three heads, namely, thermal, mechanical and volumetric, and I propose to examine these in their order.

Thermal Losses.—In an ideal compressor, all the heat generated by doing work on the air in compression would be abstracted and the compression-curve would be isothermal, the enclosed area of the indicator-diagram representing the work done being then the smallest possible. In order to approach this ideal in practice, water-injection, water-jacketing, and intercooling may be used.

I have referred to water-injection first as it was one of the earliest methods adopted, but it is now rarely met with in modern practice. To be most efficacious the water should be introduced in the form of a fine spray during compression, and this involves the use of a pump. Moreover, if the quantity used is limited to that required to be converted into vapour it is clear that the air could not be cooled below 212° F., while if a pump is avoided and the water added more freely during the suction-stroke it becomes a source of danger in a quickly reciprocating machine and requires provision made for its removal after compression.

The efficiency of water-jackets (neglecting variations in temperature of jacket-water, and assuming a constant supply) depends upon the thickness of the cylinder-walls, the ratio of cylinder cooling surface to piston-area, and the piston-speed. Hence a compressor having one large cylinder will not be so efficient as one having a number of smaller cylinders, assuming the piston-speed to be the same.

For the same reason a single-acting machine will have a higher thermal efficiency than a double-acting compressor, as each alternate stroke is an idle stroke, so that the mean temperature of the cylinder-walls will be obviously less and the heat will be abstracted better.

Intercoolers.—When compression takes place in more than one stage, an intercooler should be placed between the cylinders, and should be proportioned so as to reduce the air as nearly as possible to the temperature it had on first entering the machine. The result is naturally to reduce its volume considerably and to reduce the power required during the next stage of compression.

Although from the point of view of volumetric efficiency it is desirable, it is mainly for thermal reasons that intercoolers are used, and, other things being equal, the larger the compressor, the lower the pressure at which it becomes economical to compress in two or more stages instead of one.

Volumetric Losses.—The volumetric efficiency of a machine is the ratio of the weight of delivered air to that represented by the piston displacement, and the losses which impair this efficiency are due to clearance, valve-resistance and leakage.

The greater the clearance between piston and cylinder-head at the end of the stroke, and the greater the cubic contents of the valve-passages, the greater will be the ratio between the piston displacement and the air actually delivered per stroke; and on account of the necessity of making provision for wear this loss is greater in double-acting than in single-acting compressors.

Valve-Resistance. — With spring-loaded suction-valves the air-pressure in the cylinder during the suction-stroke is less than that of the atmosphere, owing to the resistance of the springs, and hence the importance of using mechanically-operated suction-valves which give a free admission of air during the suction-stroke.

With spring-loaded delivery-valves there will be a slight increase of pressure in the cylinder as compared with that in the delivery-pipe, depending on the design of the delivery-valve and the strength of the spring.

This excess pressure has usually no appreciable effect on the volumetric losses, but it does, together with the attenuation losses on the suction side, increase the area of the indicator-diagram and increase the power required to drive the machine.

Volumetric loss from leakage is traceable to piston-rings, stuffing-boxes, and defective valves.

It is undoubtedly equally as important in air-compressors as in steam-engines to pay careful attention to the design of piston-rings; and if all compressors were always tested for volumetric efficiency, many a machine which was credited with an excellent performance, judged from the indicator-card, would be found to owe the resemblance of its compression-curve to the isothermal curve more to leakage of air past piston-rings than to excellence of water-jacketing. Experiments I have carried out showed that, in small compressors, a considerable improvement in efficiency was obtained by fitting piston-rings of the "Willans" type instead of "sprung on" "Ramsbottom" rings.

Mechanical Losses.—The mechanical efficiency of a compressor is represented by the ratio of the work done, as shown by the indicator-diagram in the compressor-cylinder, to the power actually applied at the crank shaft to operate the compressor.

These losses are of course frictional, and are due to piston-rings and stuffing-boxes, slippers, guides, bearings, and questions of alignment when more than two bearings are used.

Valves.—I have already referred to the advantages of mechanically operated as compared with spring-loaded valves, and to give the large opening required for admitting air to the cylinder without attenuation the mechanically operated suction-valve is preferable. For delivery-valves the mechanically operated type is not as frequently met with, because of the difficulty of readily adjusting it for different delivery-pressures.

Governing.—An important matter to consider in connection with air compressors is the varying of the power exerted, in accordance with the demands for air, and so as to maintain the air pressure as constant as possible. When the compressor is steam-driven, the speed of the machine can be varied automatically by a valve operated by slight variations in the air-pressure; but when the compressor is driven at a constant speed other means are necessary. If the machine is belt driven an automatic appliance should be fitted, operated by fluctuations in pressure to move the belt from fast to loose pulley.

When electrically driven, the machine can be fitted with an automatic switch to stop and start it in accordance with the changes in pressure due to variation of demand. It is essential with these two methods to have a very large reservoir compared with the capacity of the machine, and hence many machines are fitted with an unloading device which enables the machine to run nominally without load. These operate by holding the suction-valve open during the delivery stroke or some similar method.

This method, which may be termed the "all or nothing" method, is not very

satisfactory, especially for electric driving as it gives such fluctuating loads to the motor, and methods of varying the volume will undoubtedly be perfected by compressor designers to meet this defect.

Turbo-Compressors for High Pressures.

By PROFESSOR A. RATEAU.

THE turbo-compressor, quite unknown a short time ago, is being rapidly developed, principally in the form of blowing-engines for blast-furnaces and air compressors for mines. I set myself, some years ago, the problem of finding what degree of mechanical efficiency was obtainable with such compressors. The first trial machine was constructed in 1899 from my designs by Messrs. Sautter Harlé, of Paris, and was tested during the following year. The rotating wheel was capable of attaining or even exceeding a peripheral speed of 250 metres per second. The full results of these trials were published early in 1902, in the *Bulletin de la Société de l'Industrie Minerale*, at St. Etienne. Several machines of this type have been put into use since that date, and I made a communication on the subject to the Institution of Mechanical Engineers at the Chicago meeting of 1904.

The efficiency of such compressors as determined by my method, based on the rise of the air temperature, is approximately 73 per cent.

Compressors with Multiple Wheels.—Compressors with a single wheel are only suitable for outlet pressures of about ½ atmosphere, and only work satisfactorily when the output is above a certain amount and the revolutions sufficiently high; in other words, they are limited by the resistance of the material of which the wheel is made, and also by the speed of the driving motor. By placing several wheels in series, as is frequently done for centrifugal pumps for high lifts, it is possible to obtain any desired outlet pressure. Such turbo-compressors can be used in mines.

Two years ago I applied such compressors to several purposes, and I would specially call attention to a machine placed in the mines at Bethune, which compresses the air to 6 and even 7 atmospheres, and has the further interesting feature that it is driven by a steam turbine utilising the exhaust from one of the winding-engines. This turbo-compressor has been working regularly for more than a year, and consists of four multi-cellular wheels through which the air passes in series. These wheels are grouped on two parallel shafts, each actuated by a low-pressure steam-turbine. In case the supply of low-pressure steam should fail, an automatic device is provided to supply one of the turbines with steam direct from the boilers. Between the consecutive wheels of the compressor water coolers are placed to reduce the temperature of the air heated by the compression.

These turbo-compressors follow closely the design of my centrifugal pump. They consist of a number of centrifugal wheels made in steel and keyed to the same shaft, but separated one from the other by diaphragms, in which are placed U-shaped passages, which connect the outlet of one wheel to the suction of the next. Fixed blades are placed in these passages, in order to reduce the speed of the air and to suppress eddies.

Efficiency.—The efficiency of these machines is of the same order as that of piston compressors. There is considerable misunderstanding as to the meaning of efficiency in this case. The limits of this note, however, only permit the statement that the efficiency may be estimated with reference to the real compression with the heating of the air which results therefrom or with reference to adiabatic compression, or lastly with reference to isothermal compression. In the case of multi-cellular turbo-compressors the efficiency reckoned on the actual compression reaches 73 per cent., but when referred to isothermal compression the test efficiencies are 63 per cent.; but the author believes that with improved cooling arrangements this figure will be increased. These figures may appear low compared with those quoted for piston compressors, but it should be pointed out that almost always these figures are estimated by neglecting many things. If a test is made by the reservoir method it is generally found that the efficiency of piston compressors compared with isothermal compression lies between 60 and 70 per cent. Turbo-compressors have therefore sensibly the same efficiency, and they have the great advantage that they can be directly connected to high-speed motors. When it is desired to use exhaust steam a piston compressor is unable to compete, since the cylinders of the driving engine would have to be of enormous size, and the mechanical efficiency would be very

small and far less than that of a low-pressure steam-turbine.

As already stated, the turbo-compressor at the Bethune mines was fitted with water-coolers, placed between the wheels. Recently this cooling had been more simply and efficaciously effected by a water circulation in the casing of the machine and in the diaphragms, which are made hollow for this purpose. The cooling of the air is thus carried out throughout its mass during the compression, which, therefore, is more nearly isothermal than in the case of piston-compressors.

It might be surmised that with turbo-compressors it is difficult to regulate the output as required, for instance, in the case of blast-furnaces; nevertheless I have been able to devise a system of regulation based on the property of "depression multiplicators," which gives a better result than the regulation obtained with piston-compressors.

This system has been applied to the blast-furnaces at Chasse, and the variation in the output in considerably under 1 per cent.

Electrical Transmission-Gears on Motor-Vehicles.

By A. A. CAMPBELL SWINTON, M.Inst.C.E.

In view of the somewhat barbarous method of gear-changing at present in vogue on most petrol-driven motor-vehicles, and of the fact that, crude as it is, this method continues to hold its own against all other mechanical devices, it is not surprising that attention has been turned to electrical arrangements for arriving at what is required, especially in the case of the heavier description of vehicles.

Apart from the mere transmission of the motion of the engine crank-shaft, usually with a considerable reduction in the number of revolutions per minute, to the road-wheels the chief requirements are: (1) an easily operated and preferably automatic variability of gear-ratio, so that full advantage may be taken of the maximum effort of which the engine is capable, without over-running, in obtaining the highest possible acceleration and speed for the vehicle under varying conditions of gradient, load, and surface and other resistances; (2) perfect control of the speed of the vehicle under different conditions beyond the variations of which the petrol engine is capable; (3) ready disconnection of the engine from the road-wheels, so that the former can continue to run while the latter are at rest, coupled with means for gradual reconnection so that the vehicle may start smoothly and without shock.

Important considerations that have to be taken into account in comparing electrical and mechanical methods of arriving at the above requirements are ease of working, reliability, and freedom from breakdown and derangement, weight, efficiency in terms of the power lost in the transmission, first cost, cost of upkeep, quietness and freedom from vibration.

Several arrangements of electrical transmission have been adopted, and, with varying details, may be shortly described as follows:—

(1.) The engine, which is preferably fitted with a governor, drives a dynamo which supplies energy to an electric motor, which in turn drives the road-wheels through the usual mechanical differential gear. An electrical controller of some description is fitted so that the electric current can be varied as to regulate the speed of the motor, while, either by means of the controller, or automatically by special windings on the dynamo and motor, the full power of the engine at its most efficient speed can be employed to generate constant watts made up of either a large current at low voltage, such as is required for starting and on steep gradients, or a small current at a higher voltage for running the vehicle at a high speed on the level, with corresponding variations under intermediate conditions.

(2.) Similar to No. 1, excepting that the axes of the dynamo and motor being arranged in line, a clutch of some description is arranged between them so that at top speed they can be mechanically connected together and electrical driving and all consequent losses dispensed with, the armatures of dynamo and motor acting merely as fly-wheels. In this arrangement the electrical drive is only employed for starting, and at other times when the power of the engine is insufficient to propel the car on the direct drive.

(3.) The engine drives a dynamo as in the previous cases, but instead of one motor two or more are employed, each driving a separate wheel. The mechanical differential is thus dispensed with, but the direct drive as in No. 2 cannot be arranged for. The two or more motors can either be arranged in the hubs of the wheels, when all gearing is dispensed with, or can drive the wheels through chain or toothed-wheel

reduction-wheel. The latter are the arrangements usually employed, as unless some form of speed reduction is used the motors are of necessity relatively very heavy. The employment of two or more motors enables the series-parallel system of control, so much used on electric tramcars and trains, to be adopted.

(4.) A storage-battery of comparatively small capacity, but capable of giving large discharges for short intervals, can be employed with any of the above-mentioned systems, the arrangement being such that for starting, or on hills, the battery discharges and assists the engine and dynamo in driving the motors, while at other times a part of the power of the engine is absorbed in charging the battery, the change being automatically effected by the relative voltage of the dynamo on the one hand and of the battery on the other.

(5.) In another method, in which a storage-battery is used to assist the engine when required, there are no separate dynamo and motors, but on the shaft of a mechanical transmission is fixed the armature of a machine which performs the functions of both dynamo and motor as required, automatically charging the battery when the engine has power to spare and the speed increases, and taking a discharge from the battery and acting as a motor so as to assist the engine when the latter becomes overloaded and the speed diminishes.

These systems with auxiliary batteries possess the advantage that, as the battery affords a ready means of starting the engine, the latter can always be stopped when the vehicle is at rest.

Where storage-batteries are employed, continuous currents are necessary, and apart from this, most of the systems so far used have been on the continuous-current principle, which gives large changes in gear-ratio more readily. On the other hand, multi-phase alternating currents have already been employed with some measure of success, and are a matter of considerable interest, as with them commutators and brushes, and their attendant troubles and expense are avoided, except in the case of the comparatively small exciter dynamo that is usually employed.

The chief scope for electrical transmission on motor-vehicles seems to be on heavy vehicles, such as motor-omnibuses, lorries and the like, and especially on large motor-coaches on rails, such as several of the railway companies are now running on suburban lines.

Though considerable success has already been attained with the electrical system of transmission in its various forms, there is obviously still much room for development and improvement.

The Turbine as applied to Marine Propulsion.

By the Hon. C. A. Parsons, C.B., F.R.S., M.Inst.C.E.

THE steam-turbine has been the subject of many papers read before the technical institutions of this and other countries, and its theory and practice have been dealt with in several excellent books.

The turbines now in general use may be classified under three principal types, though there are some which may be described as admixtures of these three types.

The compound or multiple-expansion type was the first to receive commercial application in 1884; the second was the single bucket wheel, driven by the expanding steam-jet in 1888; and lastly, a type which comprises some of the principal features of the other two, combined with a sinuous treatment of the steam, in 1896.

The compound type comprises the "Parsons," "Rateau," "Zoelly," and other turbines, and has up till now been that chiefly adopted for the propulsion of ships. The distinctive features of these varieties of the compound type lie principally in design, each variation having some real or imaginary advantage in view. Nearly all adopt a line of flow of the steam, generally parallel, and not radial, to the shaft.

In the "Parsons" turbine there are no compartments; the blades and guides occupy nearly the whole space between the revolving drum and fixed casing, and the characteristic action of the steam is equal impact and reaction between the fixed and moving blades. One chief object in view has been to minimise the skin-friction of the steam by reducing to a minimum the extent of moving surface in contact with the steam, and another, to reduce the percentage of leakage by the adoption of a shaft of large diameter and great rigidity, permitting small working-clearances over the tops of the blades. The other varieties of turbines have all multicellular compartments, in which revolve the wheels or discs. In them the skin-friction of the disc is greater, but is not considered serious,

and a reduction of the percentage of leakage to a minimum has been sought in the adoption of a shaft of small diameter passing through partitions stanched by metallic packings. These latter varieties are all of the impulse type, the drop in pressure being taken on the guide-blades and little or no difference of pressure occurring between the two sides of the wheels.

The second, or single-wheel type, though used extensively on land for small and moderate powers, has not received much application for marine propulsion, because of its high angular speed and the necessity of reduction gear on to the screw-shaft. The "De Laval" turbine is the chief representative of this type.

The third, or sinuous-flow type, ranks second in the extent of its application to ships, and of this type, though the "Curtis" turbine is the chief representative, yet, to it the "Reidler-Stumpf" and some others also belong; generally, it may be described as simi-compound—the stages of expansion being comparatively few; at each the "De Laval" expanding-jet principle is used, and the energy is absorbed by transfers between a few rows of fixed and moving blades. In the "Curtis" variety, the revolving wheels each carry two or more rows of blades. The skin-friction of this turbine, therefore, is more than in the "Parsons," but less than in the "Rateau" or "Zoelly" with only one row on each wheel. The leakage-coefficient is also intermediate between that of these types, but the skin-friction in the blades themselves, owing to the sinuous course at high velocity, is greater than in any of the varieties of the compound type; the erosion of the blades from higher velocity of steam is also greater, though in this latter respect the conditions are more favourable than in the single-wheel type.

After the completion of the first turbine-driven vessel, the *Turbinia*, in 1897, the progress was slow during the five succeeding years, but has rapidly increased during the last four years.

The total power of marine turbines of the "Parsons" type now completed is 385,000 h.p.

The power of marine turbines of the "Rateau," "Curtis," and other types completed is about 16,000 h.p.

Consumption of Coal in Turbine Vessels.—The consumption of steam in the *Turbinia* was determined by Professor Ewing in 1897 to be 15 lbs. per equivalent i.h.p. of reciprocating engines; this figure has been somewhat improved upon in the larger fast classes of turbine vessels, and by the addition of cruising-turbines the consumption at the cruising speeds of war-vessels has been brought to substantially the same figure as with reciprocating propelling machinery. In fast pleasure-steamers and cross-channel boats, the economy of the turbine has been found to be 5 to 15 per cent. superior to that of similar vessels with triple-expansion reciprocating engines, and about 25 per cent. superior to vessels with compound paddle engines, so that superior speeds are rendered possible. Many minor advantages are also obtained, such as less cubical space, reduced consumption of oil and stores, and reduced work for the staff.

Turbine vessels have some characteristic qualities which require to be learnt before they can be handled in the best and most economical way. This has been especially noticeable in the six years' work of the *King Edward* and the five years' of the *Queen Alexandra*, and it is found that less coal is now used and a better mean speed is maintained than during the first year. In cross-channel boats and in war-vessels, the power and economy of the reversing-turbines is much greater than in the case of the earlier turbine vessels, and this enables quicker manœuvring to be carried out with reduced boiler-power and with saving in coal.

Turbines have been found equal or superior in economy to reciprocating engines for speeds down to about 16 knots, and in some cases where large and comparatively costly turbines have been fitted, such as in yachts, down to about 12 to 15 knots.

But the solution of the problem for slow vessels undoubtedly lies in the combination of reciprocating engines and turbines, the former to deal with the high-pressure part of the expansion, and the latter the low-pressure part, covering a greatly increased total range of expansion. Such a combination, it is estimated, will effect a saving of about 12 per cent. in coal, in the case of an intermediate liner of 15 knots speed, over the best quadruple-expansion reciprocating machinery, and with a reduced weight of propelling machinery, and in a large vessel of 10 to 12 knots speed, a saving of 15 to 20 per cent. in coal-consumption over the best triple-expansion reciprocating engine. In some cases there will be an increase of capital cost, which it is estimated will be recovered in less than three years by the increased earning-power of the vessel; but in the larger vessels there will be little or no increase in such cost.

ELECTRICAL ENGINEERING NOTES.

By ANDREW STEWART, A.M.I.E.E.

Results of Electrification on the District Railway.

We have already dealt at some length with the causes which have produced the unsatisfactory results of electrifying the above railway, but we did not then possess the requisite data to enable us to more carefully analyse the nature of the trouble. We are, therefore, indebted to our esteemed contemporary, the *Electrical Review* for a good deal of useful data bearing on the results under the steam and electric systems on this line, and for a comparison between the unfortunate results obtained, and the much more satisfactory condition of affairs revealed by the accounts of the Mersey Railway. Our contemporary, in analysing these figures bears out our observations in the October, 1906, and April, 1907, issues, to the effect that the District Railway results are due, more to extraneous conditions, wholly unconnected with electric traction than to the new system of traction, and though this is to a large extent the case, electricity will in all probability have to bear the blame, as the unsatisfactory results were contemporaneous with the electrification of the line.

We give on the next page some of the more important costs per train mile under the steam and electric methods of operation, and the appalling results, chiefly in cost of power, wages, and maintenance of rolling stock and track, lead one to suppose that no ordinary number of indiscretions have been made.

The most remarkable feature of the table is that the cost of propelling the trains, *i.e.*, cost of current in the electric system, has been increased nearly three times on the District Railway, and on the Mersey Railway, quite the reverse has taken place, *viz.*, the cost of driving the trains has been reduced to about one-third. Why two opposite results should follow electrification is not clear, but evidently the cost of electric current in the case of the District Railway is a tremendous item; indeed, if the units per train mile on this line are approximately equal to that on the other electric railways—and there is no reason to suppose that they differ seriously—then the price which the District Company pay the Underground Railways seems to indicate that, whatever may be the merits of one large power house owned jointly by the interested companies, one is certainly not economy of cost to the purchasing company; for, judging by the size of this item alone, the price of current is probably twice, perhaps even three times as great as that paid by the North Eastern Railway to the Newcastle-on-Tyne Company. The difference in the case of the Mersey line is apparently equally great, though power production is on nothing like the same gigantic scale.

The increase in the cost of car repairs indicates that the foreign rolling stock on the District is not the success that some people would have us believe, though this is by no means surprising,

TABLE I. COST OF STEAM AND ELECTRIC TRACTION PER TRAIN MILE.

Items.		District Railway.		Mersey Railway.	
Steam.	Electricity.	Steam.	Electricity.	Steam.	Electricity.
		d.	*d.*	*d.*	*d.*
Wages of loco. men ...	Wages of train men ...	2·95	4·25	3·58	1·94
Coal, coke, train lighting, water	Cost of electric current ...	4·67	12·74	7·43	2·58
Loco. salaries, and general car repair salaries ...	Car salaries	·234	·28	·146	·28
Loco. repair wages, car repair wages	Car repair wages and cleaning	2·15	3·41	*	*
Loco. repair materials. loco. grease, oil and waste, car repairs material ...	Car repairs material ...	1·97	1·4	2·62	1·31
Traffic salaries and wages		5·25	3·03	6·32	3·05
Maintenance of permanent way, wages and material ...		1·45	2·82	5·3	1·12
Signals		·34	1·25	·47	·33
Train mileage		1,906,165	2,359,446	310,235	830,316

The "Signals" items on Mersey Railway includes maintenance of roads and bridges.
* No corresponding item in Mersey Railway accounts; cleaning appears under coal, coke, train lighting, &c.

as the performance of these cars on sharp curves is not such as to impress one with the stiffness of the structure. The difference in the cost of maintaining the permanent way on the District and Mersey lines calls for some explanation; the introduction of electric traction on the former doubled these costs, while on the latter it reduced them to about one-fifth.

Signalling also became an expensive item on the District, but became a much cheaper item on the Mersey line on the introduction of electric haulage, though this is due largely to the entire reorganisation of this branch of the line equipment.

As a study in contradictions these two railways would be hard to beat, and they will no doubt provide food for reflection in well balanced minds, while those seeking arguments for, as well as against, railway electrification will no doubt find all the powder and shot they want.

Apart from the striking differences already noted, one is forced to conclude that despite the extraneous competition and other factors which we referred to some months ago, the District Railway has yet to set its house in order; electrification only, cannot be blamed for increases in items which have decreased on all other lines, when electrified. If the results shown accurately represented the economic difference between steam and electricity, the latter would never have made the progress that it has, nor is it likely that the advocates of railway electrification, among whom are many of the most able men in the profession, could have been so blind as not to see such unfavourable results, if these were inherent to the system.

Electric Tugs at Niagara Falls.

A somewhat novel use for electrically driven tugs has been found by the two power companies using Niagara Falls for electric power purposes; though the tugs are quite suitable, and are sometimes employed on more orthodox work, they are specially intended to keep ice from reaching the turbines.

Originally the large quantities of floating ice which come down the Niagara River were kept out of the intake canal by a log boom placed across the entrance. With the increase of the power required, and the consequent

increase in the strength of the stream flowing into the canal, the boom proved less effective, and some other method had to be employed to free the canal from the ice which entered.

A vertical shaft was therefore constructed leading from the canal to the discharge tunnel. Into this shaft a fair amount of water was allowed to spill. It was found, however, that, unless a very large amount of water was passed into this shaft the surface current was not strong enough to divert the ice towards it. Steam tugs were therefore moored some little distance further up, with their propellers constantly in motion, which produced sufficient *surface* current to cause a considerable stream towards this shaft, and so divert the ice in this direction. It was thought that an electric tug would be cheaper to handle and more economical than a steam tug, so the Niagara Falls Power Company built a vessel 25 ft. long by 8 ft. beam and 4 ft. draught, fitted with a 75 h.p. single-phase motor, driving a propeller 52 ins. diameter by 2 ft. pitch. Current is supplied by a small carriage collector running on two overhead trolley wires and connected by a flexible cable to the tug boat.

It has been found that by varying the point at which this vessel is moored, almost all the ice which enters the canal is diverted towards the shaft.

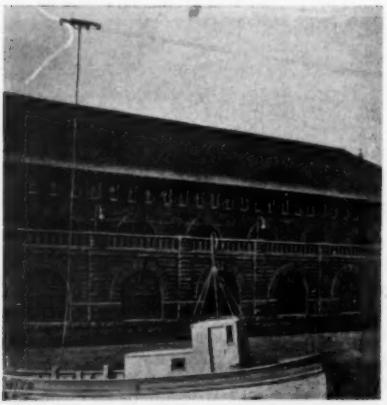


FIG. 1.—ELECTRIC TUGS AT NIAGARA.

The Canadian Niagara Power Company have built a similar, though larger, vessel, 40 ft. by 10 ft. by 6 ft., having two motors of 75 h.p., each driving one propeller 4 ft. 4 ins. diameter by 2 ft. pitch. Fig. 1 illustrates the smaller boat in the canal of the Niagara Power Company. The trolley wire pressure is 1,100 volts. Although the use of the tugs for this purpose is very limited, yet the general arrangement is quite applicable to canal towage, and in that respect forms an interesting addition to the many types already illustrated and described in our columns.

A Modern Electrically-Driven Cement Works.

Every structural engineer knows the "Pioneer" brand of Portland cement, but it is not equally well known that electricity now plays an important part in its production. Messrs. Casebourne & Co., of West Hartlepool, have a cement works covering five and a quarter acres, devoted to the production of this brand of Portland cement, and they have recently substituted electric motors for the oil engines previously employed to drive the works. Power is not generated on the premises, but is purchased from the Cleveland and Durham Electric Power Co., and three phase motors are used throughout the works.

One of the raw materials, chalk, is brought to the Tees by sea, the clay is obtained locally. The chalk is hoisted from the ships by grabs, and emptied into the hoppers of two large elevated crushers, through which it passes into a "Hunt" bucket conveyor, each bucket of which is mounted on a central pivot which tips when the conveyor has reached the wash mill. This conveyor is driven by a 20 h.p. three-phase motor.

Clay is added here, and three parts of chalk to one of clay is thoroughly mixed with water and the resultant slurry is then conveyed by another bucket conveyor to the tube mills,

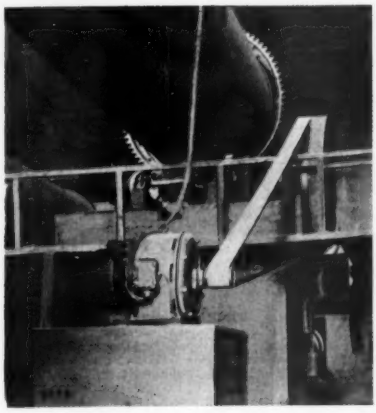


FIG. 2.—15 H.P. MOTOR DRIVING TUBE MILL.

where the slurry passes through a long hollow cylinder partially filled with flint stones, which revolves slowly, and ensures that the slurry is thoroughly mixed, and free from granular pieces of even the smallest size. These slurry mills are driven by 15 h.p. "Westinghouse" motors (Fig. 2), the first speed reduction being by belt, then spur and bevel gear, to a worm and wheel, the latter being fixed on the outside of the tube mill. These motors are of the variable speed type, the speed being varied from 400 to 800 revs. per min., depending on the quantity of "slurry" passing through the mill.

The slurry pumps, it may be noted, are driven from a line shaft, which is operated by a 100 h.p. motor, which also drives the clinker coolers, and the shaker conveyor.

From the tube mills the slurry passes to a mixer, which keeps it in motion until it is fed into the rotary kilns, which consist of an iron cylinder 100 ft. long and 6½ ft. diameter lined with fire-brick, into one end of which is blown pulverised coal, which burns with an intense gas-like flame. As the slurry passes down this rotary kiln, which is driven in a similar manner to Fig. 2, the water is evaporated and the solid matter converted into clinker, which is cooled in a clinker cooler by contact with cold air as it emerges at the lower end of the mill. At the end of this clinker cooler, it falls into a shaker conveyor, which transfers it to a bucket elevator, which in turn conveys it to a 300-ton ferro-concrete silo, over the dry mill.

The shaker conveyor and clinker coolers are driven from the line shaft already mentioned, but the bucket elevator is driven by a 15 h.p. induction motor.

The material falls down two shoots from the silo to a pair of "Krupp" steel ball mills for preliminary grinding; this ball mill is driven by a 200 h.p. motor. The material is now conveyed by another bucket elevator to an "Avery" automatic weighing machine, and from this, by an inclined screw conveyor into two "Krupp" dry tube mills, from which the material emerges as cement. This tube mill is also driven by a 200 h.p. motor (Fig. 3). A screw conveyor, driven by a 50 h.p. motor, conveys the cement to the warehouse, which holds some 6,000 tons of finished cement.

It should be noted that the coal used as fuel in the rotary kilns is first dried on the premises till it contains less than 1 per cent. of moisture; it is then ground by two ball mills and two tube mills, driven by a 150 h.p. motor, exactly as the cement is treated. This powdered coal is then conveyed by a screw conveyor to hoppers at the end of the kiln

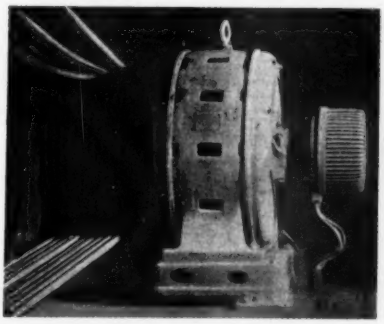


FIG. 3.—200 H.P. DRIVING TUBE MILL.

FIG. 4.—ELECTRICALLY DRIVEN COAL TRANSPORTER AND WEIGHER.

house, where it is fed into each kiln, the feed being regulated by a "Reevs" variable speed gear.

Air is supplied to the kiln by fans which take their air supply from the clinker coolers; it is therefore heated when mixed with the powdered coal.

An Electrically-Operated Coal Handling Plant.

The Bournemouth Gas and Water Co. have recently installed a very complete plant for removing coal from the ships, and transporting it to storage bins or to the retort house. Fig. 4 shows the transporter, which consists of a lattice girder bridge having a span of 180 ft. The bridge is of triangular section, the trucks run on the under side, which is, as will be seen, like the apex of the triangle, but inverted. There is a hinged extremity 92 ft. long extending over a road and over the quay, so that the grab may be lowered directly into the hold of the ship. The back, or inshore, support of the bridge, carries a coal crusher and hopper leading to a conveyer feeder, the coal passing through the former on its way to the conveyor.

A hopper weighing machine is carried by a lattice girder frame suspended from the side of the bridge. This is seen some distance down the span, and the grab is discharging into it. The coal is raised by the grab from the hold of the vessel, and may be discharged either in heaps anywhere within the span, or into the coal crusher and conveyor at the inshore end, or it may be lifted from the heaps and discharged into the crusher. In any case the arrangement of the weighing machine makes it possible to weigh the coal every time it is moved.

The transporter bridge is, of course, electrically illuminated, but the feature of special interest is a small scale model of the transporter inside the driver's cab, seen near the seaward end of the span. On this indicator the traveller, grab, and weighing machine move automatically, in harmony with the movements of the gear outside; it is thus possible to unload, weigh, and stack an entire cargo of coal during a fog so dense that the driver can see nothing outside his cabin, yet with the absolute certainty that everything will be carried out as desired.

NOTES AND COMMENTS.

THE question of the position of the Naval Engineer and Admiralty Policy is one which has, for some time past, aroused a peculiar interest amongst engineers throughout the kingdom, and its importance from the point of view of efficiency is sufficiently evidenced by the fact that it is now occupying the attention of a Service Committee, specially appointed by the Admiralty early in the year.

This committee, it appears, is composed of officers from the executive engineer and marine branches, and it was to be presumed that every care would have been taken that those selected were thoroughly representative of their respective branches and yet be free from that traditional animus which, unfortunately for naval efficiency, still prevailed between the deck and engineer officers, but the existence of which had been so repeatedly denied officially in Parliament and elsewhere. The public estimation of the position proved, however, to be only too true, as, according to Mr. Dugdale, the president of the North-East Coast Institution of Shipbuilders and Engineers, who referred to the question at the closing meeting of that society; not only did the selected executive officers on the committee take a consistently hostile attitude throughout the proceedings, but subsequent to the signing of the majority report, which was in the nature of an unsatisfactory compromise, they submitted an independent report, which in its studied insults to engineers and engineering he hoped was without parallel in the British or any other navy in the world, and demonstrated beyond question that even selected officers in high command cannot, when engineer officers were concerned, divest themselves of that intense and bitter prejudice which was so seriously affecting naval efficiency, and which must inevitably wreck the success of the new scheme with regard to the engineer branch of the service.

The engineer branch is still by far the most unpopular in the navy, the work is hard, dirty and disagreeable compared with the other branches; the incessant strain is great and the official recognition practically *nil*. As a consequence there is a very natural reluctance on the part of the new cadets to become engineer officers, and as, according to Mr. Dugdale, it is the obvious intention of the executive branch to persist in a policy of repression, the fear of the boys and their parents appears to be justified. This is all the more lamentable by reason of the depletion in the numbers of the highly skilled artificers and the conversion of firemen into engine-room watch keepers; in fact, as Mr. Dugdale pointed out, the inevitable developments are likely to be so serious that it is the bounden duty of the professional marine engineers of this country to give expression to their views on a question which is national in its importance.

What has been repeatedly advocated is that engineer officers should be placed in military control over their own men, with power to deal with minor offences committed in their department, such as were now dealt with by the senior deck officer, to whom the necessary authority is delegated by the captain of the ship, and also that there should be complete identity between the existing engineer officers and those of the new creation with regard to uniform, title, pay, promotion, seats on court martial, retirement, pension, &c., in fact in everything except succession in the line of command of ships.

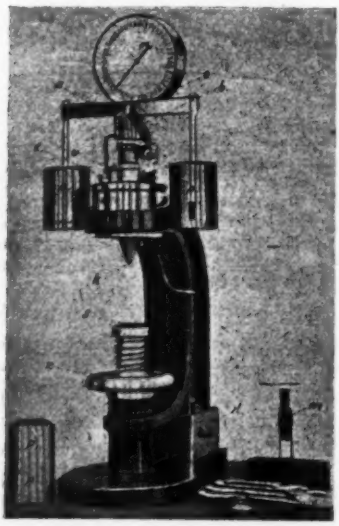
With regard to the executive curl, it is stated that the executive officers on the committee advised that it should be worn upside down by the engineer officers, and requested their lordships to inform them what they had done that they should be expected to wear the same uniform as the engineer officers. One of these officers also desired to know whether the commanding officer of the ship should be on the same footing as the man who drives the engines. Without enlarging on the slur conveyed by this question, the obvious reply is that the primary object of the new scheme is that the officers of equal rank in each of the military branches should be on an absolute equality, as is the case in the United States and Japanese navies, and until this is achieved the position must become increasingly grave.

IRON, STEEL, AND THE FOUNDRY.

Conducted by PERCY LONGMUIR.

FOUNDRY PRACTICE.

Brinell's Method for Testing the Hardness of Metals.—Messrs. J. E. Stead and T. Greville-Jones describe the Brinell ball test, in a paper read before the Cleveland Institution of Engineers. The principle of the method lies in forcing a hard steel ball into the metal to be tested under a definite pressure, measuring the diameter of the impression and from the diameter calculating the spherical area of the concavity, the Brinell hardness number being obtained by dividing the maximum pressure into the area so found. As first conducted this method required a tensile testing machine, but recently the Aktiebolaget Alpha, of Stockholm, have designed a machine specially arranged for hardness tests. Reference to the appended illustration will show this machine to consist of a hydraulic press acting downwards, the lower part of the piston being fitted with a 10 mm. steel ball *k*, by means of which the impression is made on the surface of a specimen supported on *S*. The pressure is obtained from a small hand pump and is recorded on a pressure gauge. In conducting the test a polished specimen is placed on the support *S*, which is raised by means of the hand wheel *r*, until it comes into contact with the ball *k*. On closing the valve *V*, which cuts off communication between the press cylinder and the oil cistern, and applying a few slow strokes with the hand pump, the requisite pressure to force the ball downwards will be produced, thereby causing a slight impression in the sample of metal. As soon as the required pressure is obtained, the upper piston with the controlling apparatus is forced upwards, whilst the corresponding pressure is indicated by the gauge. The diameter of the depression is measured by means of the microscope *m*. A series of "Clarence" pig irons and foundry mixtures were tested, with the following results:—



MACHINE FOR TESTING HARDNESS OF METALS.

Clarence Pig Iron.

Pressure	3,000 kilos.
Diameter of ball	10 mm.
	Hardness number.
Glazed iron	average hardness = 143
No. 1	" = 104
No. 3	" = 112
No. 4 foundry	" = 156
No. 4 forge	" = 160
Hard forge	" = 197
Grey mottled	" = 153
White iron	" = 418

Foundry Mixtures.

Fracture.	Brinell's hardness number
No. 4 foundry	131
Do.	143
Do.	143
Do.	153
No. 4 forge	170
Do.	187
Broken cylinder from a Clement motor car engine	207

Other Metals.

Spiegeleisen = 10 per cent. Mn.	782
Chilled castings = Hard face	445
" " Middle mottled ..	350
" " Grey back	207
Hardened steel file	560
Horse-shoe magnet = Magnetised part ..	512
" " Soft part	207
Rail steels, 0·4 to 0·45	200 to 210
Tinplate bars, 0·1 per cent. C	112
Purest Swedish iron	87

The Grey Iron Foundry as a Business Venture.—In discussing this topic before the American Foundrymen's Association, Mr. T. D. West gives a series of twelve preliminary "points" which in themselves are quite sufficient to deter non-technical men from entertaining the foundry as a business venture. Passing these deterrent points, some general advice is summarised in the following.

First. Investigate the demand for the class of castings it is intended to produce and the competition that will have to be faced.

Second. Select a site central to the market, and in building commence as small a scale as practicable, but allow for future extension without having to tear down too much of the existing plant.

Third. In the search for machinery and appliances obtain, as far as possible, the experience of others, and investigate latest improvements.

Fourth. Avoid, as far as possible, the purchase of second-hand tools and plant.

Fifth. When seeking orders, if not competent to quote prices, take the advice of manager or foreman.

Sixth. When commencing do not be in a hurry, but go slowly, and the chances of error will be lessened.

Seventh. Procure sufficient working capital, and leave an opportuity to obtain a surplus over and above what is considered necessary.

As to the amount of preliminary knowledge before commencing, the natural answer is found in a full grasp of the practical and business side of foundry practice. This, however, is not always realised and to-day we have bankers, lawyers and even clerical men assuming the management of foundries. Finally, Mr. West contends that brains and intelligence do not always stand for experience.

The Steel Foundry as a Business Venture.*—Mr. W. M. Carr, the author of this paper, evidently possesses a more sanguine temperament than Mr. West, for we are told that the capitalist investing in the steel foundry has now better assurance of dividends than at any time in the past. Concerning the actual capital involved no definite statement can be made, owing to varying local conditions, but the following generalities will serve as a broad guide. The net profit on a given amount of capital does not vary with the size of the plant, for small plants can show as great a percentage of profits as larger ones. The demand will largely control the size of the plant, and for an illustration a plant yielding 150 tons daily may be taken. This plant would employ about 1,800 hands, and would require a large amount of ground with good shipping and receiving facilities. There should be at least five 25-ton open hearth furnaces with four in regular operation. The furnaces would be served with electric-charging machines, and the moulding and casting floors by several 35-ton cranes. Hoists and light travellers would be required in cleaning, finishing and shipping departments. The plant should have a well-equipped power-house with engines and generators, pattern and machine shops, yard locomotives and liberal moulding machine installations. This plant, as described, could not be started without $1,000,000 capital, and the cost of erecting substantial buildings with crane runways and complete equipment would amount to at least $750,000.

The following estimate, on the basis of ton capacity, will cover plants varying from 80 tons per day, with a two 25-ton furnace plant, to one with five 25-ton furnaces, producing 150 tons daily.

	$
Furnaces only	1,200
Gas producers, gasmains or oil tanks and accessories	600
Buildings, 800 sq. ft. per ton at $ 1·25	1,000
Power, machinery, cranes, hoists, ladles, drying ovens, &c.	2,300
Total cost per ton	5,100

Such an equipment, with a good demand for castings, can show 25 per cent. on the investment.

Following this, Mr. Carr considers various details, and amongst them refers to the "Tropenas" process which, in his opinion, will not reach the development promised by the basic open hearth. The "Tropenas" process, however, is well suited for special purposes when certain kinds of steel are wanted in small quantities, but for general uses its own weaknesses are detrimental, preventing competition with open hearth methods. In considering basic or acid open hearth practice, it is stated

* American Foundrymen's Association.

that, for castings, the basic process by offering the greatest latitude in the selection of stock is the most suitable one. Finally, an open hearth plant as an accessory to a grey iron foundry is considered, and it is shown that in certain cases the iron founder may, by the installation of a small open hearth furnace, profitably produce steel castings in conjunction with iron castings.

The Malleable Foundry as a Business Venture.* — Under this heading Dr. Moldeuke gives some pertinent advice to those intending to embark on the perilous sea of malleable iron founding, and at the outset prefaces by stating:—"Unless you have at least five tons daily to make—don't." When one has personally gone through the building of a large establishment and has the making of hundreds of thousands of tons of malleable castings behind him, caution is the order of the day; and unless the quantity is sufficient and deliveries from outside unsatisfactory, it is wisest to buy from existing plants rather than to venture upon the little known fields of the heat treatment of white cast iron. However, Dr. Moldeuke goes very fairly into the advantages and disadvantages of adding a malleable plant to existing works. Taking advantages first, these are summarised as follows:—

1. The expanding market for malleable castings and the great room for improvement in most of the producing works gives a living chance to the man to go in to the business, provided he understands it thoroughly.

2. In times of prosperity plants in existence must turn away large quantities of offered work, being unable to produce it.

3. The moment the malleable casting works are full, deliveries are so desperately bad and slow that attention is turned directly to new enterprises coming in.

4. The adaptability of the malleable casting to specialities is such that the beginner has a good chance of success, provided his speciality is good.

5. Where absolutely good material is required, it pays the consumer of malleable castings to enter into their manufacture, provided he has sufficient tonnage. Only he who knows how easily one can slip up on the quality of the malleable casting, also knows how often this is done and the customer is not the wiser.

6. The malleable product from its adaptability to specialities, and comparatively light castings at that, means a production in quantity of each separate piece. Hence it is not a question of half-a-dozen castings, but often times several hundred thousand, or in other words, continuous production with comparatively well-regulated and systematised shop cost.

The disadvantages which follow from the above are:—

1. The expanding market while making room also leaves very empty shops in dull times, for the existing plants usually expand with each high wave of prosperity, and manage to hold desirable customers.

2. When the work turned away by the full plants is taken by the beginner it is at lower prices, or if at high prices, is lost again when these fall.

3. The high capital required is a great detriment, being about four times as much as for the same tonnage in grey iron for the works alone. This means more than appears on the surface. The malleable casting process is intricate, the chances of loss are great, and it takes fully two years to get a desirable class of men in the shop. Hence the chances of no profit, if not worse, for a long time, which must be met and carried until success appears. To give an instance, a rough calculation of the cost of a shop to produce 50 tons of castings daily would be about $250,000. By the time that shop would actually be producing 50 tons daily at a normal shop cost over double the amount of money will have been expended. Then, however, with a good market, the shop will pay handsomely.

4. The high grade of skill required results in high salaries in the case of important men and eternal vigilance in the works.

5. As a last disadvantage, Dr. Moldeuke includes competition which at times is more severe than in the case of grey iron castings. One reason for this competition is the existence of specialities which sell under patents and for as high a price as the community will stand. Hence this velvet can cover a deficit to keep the rest of the works in operation. This, of course, is hard on foundries having no specialities, and hence again the necessity of having abundant capital until such a speciality is found.

Finally, in summing up, the author states: "With a good speciality and sufficient daily tonnage it is good policy to enter the malleable casting industry as a business venture; but with less than five tons daily, with insufficient working capital and men not thoroughly trained in this line, it is better to leave it alone.

The Growth of the Steel Casting Industry.— In the June issue of the

* American Foundrymen s Association.

Foundry attention is drawn to the development in America of the steel casting industry. Within six years the production of steel castings has increased over 500,000 tons. In 1900 the total output of Bessemer open hearth and crucible castings amounted to 192,803 tons, as compared with 713,517 tons of basic and acid castings alone in 1906. This growth is largely due to the substitution of steel castings for grey iron and forged sections, although heavy inroads have been made on car bolsters for freight service formerly built from structural shapes. The processes of manufacture, particularly the converter and open hearth, have undergone wonderful changes, and many of the earlier difficulties have been overcome. The heavy losses associated with this practice until a comparatively recent date have been reduced to a minimum, and the selling price of the product has declined proportionately. The heavier sections are now being sold almost on a par with grey iron, whilst lighter castings are offered at only a slight advance. Other contributory causes to the growth of steel castings are found in the adoption of green sand moulds and the development of the basic process. The figures given show a really remarkable growth, but it is singular to note that coincident with the development of the open hearth and converter processes, the production of crucible castings shows a slight increase year by year.

Oil-burning Turbine-driven Torpedo Boats.

Messrs. J. S. White & Co., Limited, of East Cowes, have, according to *Engineering*, constructed the five torpedo boats which they have had on order for the British Navy. They are 175 ft. long, 17 ft. 6 in. beam, and 10 ft. 9 in. in depth, the displacement at 5 ft. 8 in. draught being 245 tons. The vessels are fitted with a whale-backed forecastle surmounted by a bridge carrying a 12-pounder gun, another 12-pounder gun being mounted aft. Three torpedo launching tubes are provided. These boats are provided with turbines of the "Parsons" type, and are constructed to burn oil fuel.

The boilers, two of which are fitted in each vessel, are of the "White-Foster" type, Fig. 5 showing one in its completed form with all its fittings and liquid fuel nozzles. The ratio of grate to heating surface is 1 to 60, and 2 sq. ft. of heating surface is provided for the equivalent of one indicated

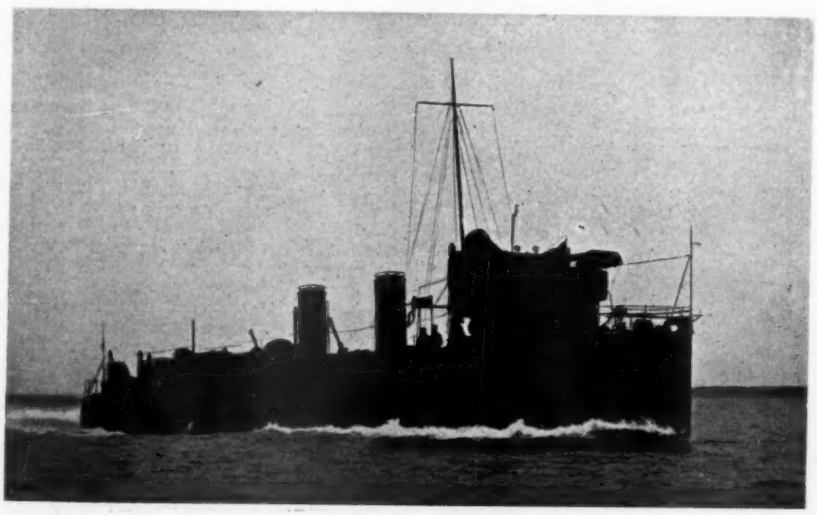


FIG. 1.—OIL-BURNING TURBINE-DRIVEN TORPEDO BOAT.

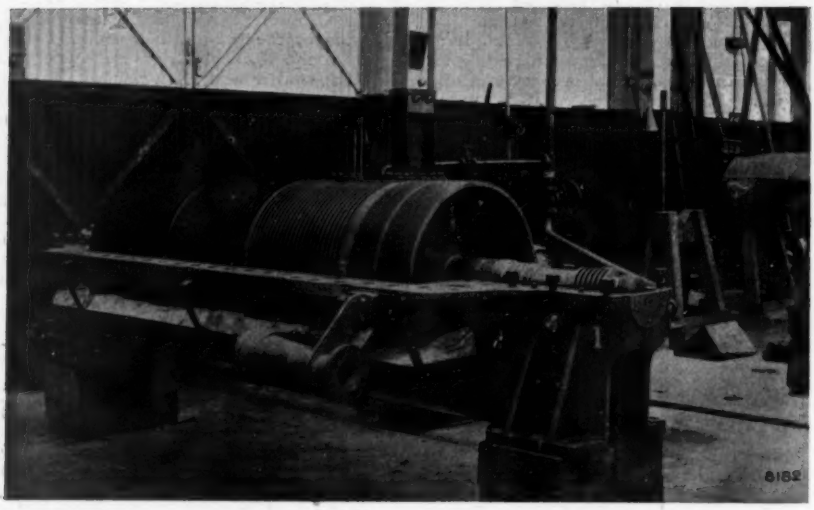


FIG. 2.—THE ROTOR OF THE CRUISING TURBINE.

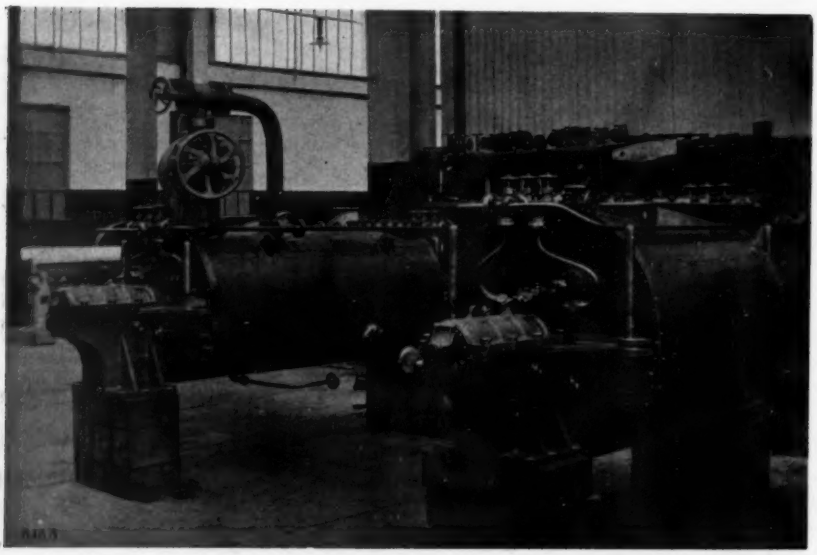


FIG. 3.—THE HIGH-PRESSURE AND INTERMEDIATE TURBINES.

FIG. 4.—THE LOW-PRESSURE AND ASTERN TURBINE.

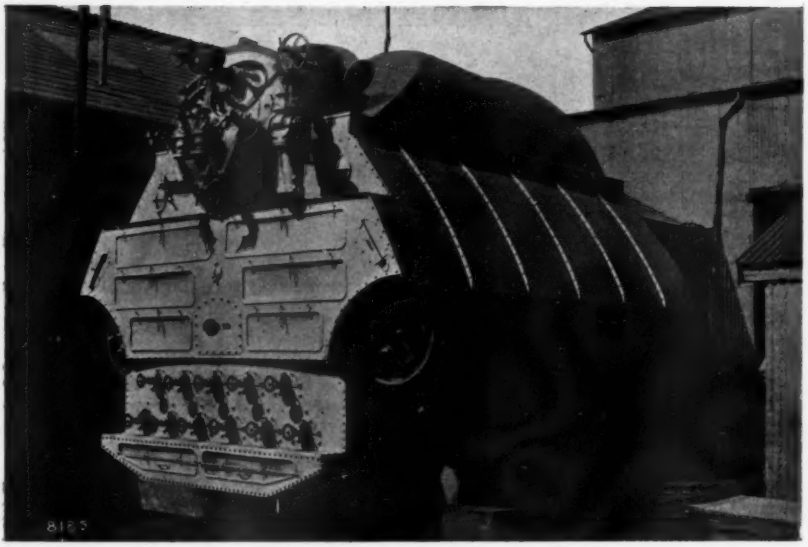


FIG. 5.—THE "WHITE-FOSTER" BOILER, COMPLETE WITH FITTINGS AND LIQUID FUEL NOZZLES.

horse power. There are three shafts, on the centre one of which is a cruising turbine and a low pressure ahead and astern turbine, the latter two within one casing. On the port shaft a high-pressure turbine is connected, and on the starboard shaft an intermediate turbine. All four ahead turbines are employed for speeds up to 16 knots, the cruising turbine taking steam direct from the boiler, and passing it on to the high-pressure on the port shaft, and thence to the intermediate turbine on the starboard shaft, to the low-pressure turbine on the centre shaft, and finally to the condenser, which is on the port side.

For speeds above 16 knots the steam is shut off from the cruising turbine—which then works *in vacuo*—and passes direct to the high-pressure turbine, thence to the intermediate, the low-pressure, and finally to the condenser. The turbines are bladed on the "Parsons" system, and the details correspond with those generally adopted in torpedo craft. The illustrations, for which we are indebted to Messrs. J. Samuel White & Co., show, in Fig. 2, the rotor of the cruising turbine, from which it will be seen that there are three stages; in Fig. 3, the high-pressure and intermediate turbines, which are considerably shorter than the cruising turbine. On this view there is seen the valve for the passage of steam from the boiler direct to the high-pressure turbine. Fig. 4 shows the rotor of the low-pressure and astern turbines in place, with the upper part of the casing raised, and the thrust-shaft and vertical supports for lifting the upper part of the casing.

The trials showed a speed on the measured mile of 27·107 knots, and a mean speed for eight hours of 26·36 knots, with an oil consumption of 20·758 tons.

We understand that the builders have under construction four more vessels of the same type of slightly increased dimensions, displacing 256 tons at a draught of 5 ft. 10 in., and that two 33-knot destroyers are also in course of construction.

NEW MACHINERY AND APPLIANCES.

The Editor cordially invites early particulars of New Machinery, Improvements, Novelties, &c., for inclusion under this section.

Variable-delivery Constant-stroke Three-throw Pump.

The demand for a three-throw pump with an economically obtained variable delivery has for some time been a growing one, and so far has only been met by arrangements for varying the length of the actual stroke made by the plungers; these arrangements have necessitated the transmission of power through more or less complicated gearing, and have been open to the practical objection that when working on a short stroke, ridges form on the plungers, which, when the stroke is lengthened, are apt to damage the packing and destroy the efficiency of the pump.

Messrs. Thwaites Bros., Limited, of Bradford, have, in conjunction with Mr. T. H. C. Homersham, recently perfected a pump in which the results aimed at have been attained in what is claimed to be an original manner, and one which is free from the above-named objections. In this pump the desired result is obtained by driving a small cam shaft direct from the crankshaft, the cams on the shaft being arranged beneath the suction valve stems. When pumping full bore, these cams merely follow the rise and fall of the suction valves,

but as the relative angularities of the cams and the crank pins can be altered whilst the pump is running, by merely moving a small hand lever, the discharge can be varied from nothing to full bore. By this lever the relative angularities of the cams and crank pins being altered, the suction valves can be held open during the whole or any required portion of the delivery stroke of each plunger.

It is, of course, obvious that during that portion of the stroke when the suction valve is mechanically held open, no power is exerted beyond that necessary to circulate the water through the pump itself at no pressure, and that a perfectly even torque is obtained whatever delivery the pump is set for.

In practice the arrangement is stated to work most successfully, and when driven by an electric motor, the amount of current used is found to vary exactly with the position of the lever regulating the cam shaft, and consequently the delivery of the pump.

We hope later to give a detailed and illustrated description of this pump.

3½-in. Horizontal Drilling, Tapping, and Milling Machine.

The accompanying illustration is that of a very fine horizontal drilling and tapping machine recently designed and built for high speed work by Messrs. W. Asquith, Ltd., Halifax. The spindle is 3½ in. diameter in the driving part, but much larger in the sleeve in which it revolves, and by which it is supported when out at full traverse, making it practically equal to a spindle of a larger nominal diameter. The absence of side twist is a further point to be noted, the spindle working centrally in the strong standard, as will be seen from illustration. The spindle has a 20-in. feed and four changes of self-acting traverse operated by gears under immediate control. A powerful friction drive admits of the feed being stopped or started immediately, so that the spindle can be withdrawn at high speed almost simultaneously with the knocking off of the feed, the motion being almost equal to that of a sensitive drill. The feed can also be stopped, started or reversed from the operator's position by the slide, which carries the double gear. The slide is of improved form with large bearings having rectangular guides, ensuring great durability, and is balanced by means of weights sliding on rods. It has a fine hand adjustment vertically, also an improved power traverse by means of a screw, easily and quickly manipulated through a hand wheel, controlled from the platform. The standard is of very powerful section, having exceptionally deep webs, a large base, and is thus suitable for executing the heaviest work to best high speed advantage without deflection. The standard can be adjusted along the bed by power motion, and there is also provided three changes of variable self-acting feed with a fine hand traverse controlled similarly to the vertical traverse of the slide. This renders the machine suitable for either horizontal or vertical milling and facing.

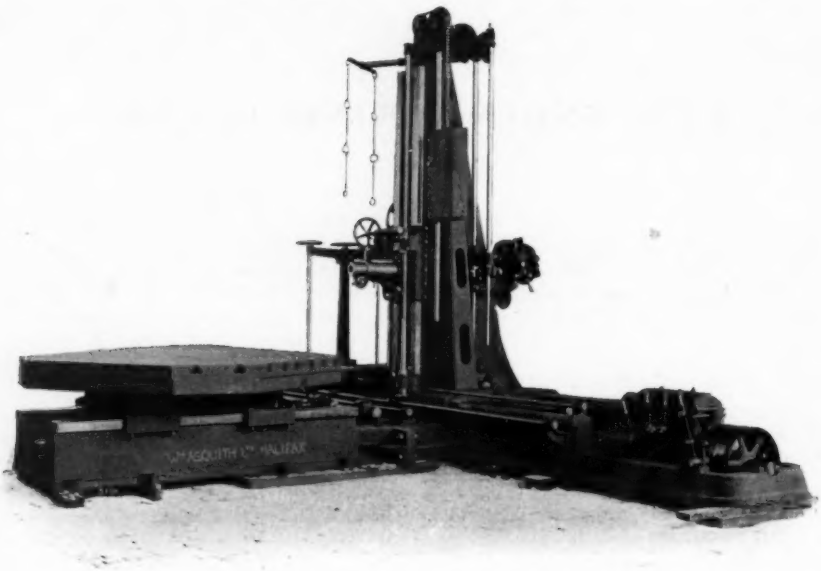
The self-acting milling feeds are arranged at the rates of 2, 5 and 10 in. per minute for the width of facing. These self-acting motions are independent of the mechanism driving the spindle.

The standard is mounted upon a strong bed of sufficient length to give a cross traverse to the spindle of 10 ft., and at right angles to this is bolted a strong bed carrying the work table. The latter is 8 ft. square, with the corners taken off, and is provided with planed T slots for large work. It has a motion to and from the spindle of 4 ft., which is operated by power, and has also a power rotary motion through a complete circle controlled from platform. Objects fitted centrally on the work table can thus be admitted up to 16 ft. diameter. Stops are provided at every 90 deg., and the fine adjustment is made by hand. The bed carrying the table is of sufficient length to allow of the maximum adjustment to same being attained without overhanging of the carriage, thus ensuring great rigidity.

The drive is by means of an improved gear box, having steel gears giving eight changes of speed, or, with the double gear, sixteen speeds to the spindle, ensuring a large range for various classes of work. An automatic trip motion with safety stop is also provided for the spindle feed.

The platform which carries the operator rises with the slide when in top position, so that he always has the working parts of the machine under immediate control. The height over which the spindle is adjustable is from 6 in. minimum from the top of the table to 8 ft. 6 in. maximum from the table, and, as previously stated, the width which it will drill is 10 ft., so that it will be seen the machine has very large range.

The machine has been built to meet the



HORIZONTAL DRILLING, TAPPING AND MILLING MACHINE.

requirements of a well known firm of marine engineers and is a similar tool to one previously supplied by Messrs. W. Asquith, but of larger dimensions. The advantages of this type for drilling and tapping large marine work which can be easily and quickly operated upon on all sides, will be apparent, while the usefulness of the tool is considerably increased by its ability to deal with milling and facing operations over such a large area, obviating the necessity of removal of the parts and re-setting up on other machines. The weight of the machine is about 22 tons, its length overall 31 ft., height 16 ft., and depth from back to front about 19 ft.

THE ENGINEERING PRESS.

In this section is presented every month a list of the more important articles appearing in the Engineering Press and of the leading papers read before the various engineering institutions. Full names, addresses, and published prices of the publications indexed are printed each half-year in the volume index.

Civil Engineering.

The North Sea: Its Physical Characteristics, Tides and Currents, I., II. By W. H Wheeler, M.Inst.C.E. *The Engineer*, *17th* and *24th May*, 1907.

Smallheath Bridge, Birmingham. *Engineering*, *24th May*, 1907.

The New York Subaqueous Tunnels, V., VI. By Chas. Prelini, C.E. *Engineering*, *24th May* and *7th June*, 1907.

Notes on the Erection of Bridges, IV. *Railway Engineer*, *June*, 1907.

Moving Loads on Railway Under Bridges. By H. Bamford, M.Sc., A.M.Inst.C.E. *Engineering*, *31st May*, 1907.

The Modern Development of British Fishery Harbours, IV. By H. C. M. Austen. *Engineering*, *31st May*, 1907.

A Large Reinforced Concrete Dam at Ellsworth, Maine. *Engineering News*, *23rd May*, 1907.

Projected Steel Arch Bridge over the East River at Hell Gate, New York City. *Engineering News*, *30th May*, 1907.

Study in Masonry Dams and Walls of Reservoirs. La Houille Blanche. *April*, 1907.

The Sandy Hill Bridge over the Hudson River; a Long Reinforced Concrete Arch Bridge with Block Facing. *Engineering News*, *9th May*, 1907.

The Oakland Bridge, Pittsburg, Pennsylvania: a Steel Arch without Hinges. *Engineering News*, *16th May*, 1907.

Setting out Curves. By T. G. Bocking. *Engineer*, *17th May*, 1907.

Cantilever Bridge on the Schwarzwassertobel (Switzerland). *Le Génie Civil*, *1st June*, 1907.

Building.

The "Compressol" System of Making Foundations. *Engineering*, *7th June*, 1907.

Heating and Ventilation.

The Heating of Store Houses. By H. O. Lacount. *Proceedings American Society of Mechanical Engineers*, *June*, 1907.

Materials and Measurements.

Methods and Economic Aspects of Modern Timber Preservation. By G. A leman. *Proceedings Engineers' Club, Philadelphia*, *April*, 1907.

The Corrosion of Steel in Reinforced Cinder Concrete. By W. H. Fox. *Engineering News*, *23rd May*, 1907.

Boilers, Furnaces, and Fuel.

Dust Fuel Stokers and Auxiliary Plant. By W. R. Harrison. *Iron and Coal Trades Review*, *24th May*, 1907.

Construction of Natural Draught Furnaces. By Walter J. May. *Practical Engineer*, *31st May*, 1907.

How to Judge Boiler Waters from Analyses. By J. G. A. Rhodin, F.I.C. *Engineer*, *31st May*, 1907.

Modern Power Gas Producer Practice and its Applications. By Horace Allen (*continued*). *Practical Engineer*, *24th May*, and *7th June*, 1907.

The Regulation of Boiler Feeders, III., IV. By C. S. Towne. *Electrical World, New York*, *4th May*, *1st June*, 1907.

Liquid Fuels for the Gas Engine. By C. E. Lucke. *Engineer, Chicago*, *15th May*, 1907.

Gas Producers (Pulverised Fuel) Marconnet System. *Le Génie Civil*, *11th*, *May*, 1907.

Experiences with Superheated Steam. By G. H. Barrus. *Proceedings American Society Mechanical Engineers*, *May*, 1907.

The Flow of Superheated Steam in Pipes. By E. H. Foster. *Proceedings American Society Mechanical Engineers*, *May*, 1907.

Superheated Steam in an Injector. By S. L. Kneass. *Proceedings American Society Mechanical Engineers, May*, 1907.

The Performance of "Cole" Superheaters. By Professor W. F. M. Goss. *Proceedings American Society Mechanical Engineers, May*, 1907.

Superheat and Furnace Relations. By. R. P. Bolton; The Economy of the Long Kiln. By E. C. Soper; Entropy Lines of Superheated Steam. By Professor A. M. Greene; Materials for the Control of Superheated Steam. By M. W. Kellog. *Proceedings American Society Mechanical Engineers, June*, 1907.

Engines and Motors.

Working Experiences with Large Gas Engines. By Cecil A. St. George Moore, before *Society of Engineers, 3rd June*, 1907.

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TRADE LITERATURE.

Direct Gas Fuel, Ltd., 17, Victoria Street, S.W. Descriptive circular of Gregory's Patent Smoke Preventing and Steam Generating Apparatus. This consists of a cast-iron chamber which is fitted internally around the furnace door opening. Air is drawn in by two holes of about 3½ in. diameter situated in each side of the door, into the hot air chamber, by means of a specially constructed nozzle which emits a small jet of steam, which co-mingles (1) with hot air in the retort pipes, and (2) with the volatile gases given off by the fresh coal, forming a combustible gas which is immediately and completely burned instead of passing off in the form of smoke. A small valve regulates the apparatus to suit the character of the fuel. In a report of a test accompanying the circular it is stated that 10 per cent. more water was evaporated per lb. of coal; the temperature of the fire reached, with the apparatus in use, 2,284° in 11 minutes, and 1,850° in 36 minutes without the apparatus, and that the time of raising steam from 80 to 100 lbs. was, with the apparatus, 3½ minutes, and without, 8½ minutes.

R. Waygood & Co., Ltd., Falmouth Road. S.E. Reprint of catalogue relating to lifts for private residences.

W. T. Glover & Co., Ltd., Trafford Park, Manchester. The firm's sixth almanac has just been issued in a new form whereby it can either be suspended on a wall or placed on desk or table, thus rendering it more accessible for reference. It is as bright and full of interest as ever.

The Consolidated Pneumatic Tool Co., Ltd., Palace Chambers, 9 Bridge Street, Westminster. 1907 catalogue of Pneumatic Tools, containing not only a detailed description of the various tools made by this firm, but full instructions for use. All parts are separately illustrated and numbered throughout for reference; in short, the list forms a very handy compendium on the subject of pneumatic tools and is all that a catalogue should be.

Geo. Kent, 199-201, High Holborn, W.C. New list of Sanitary Ice Safes and Refrigerators. By this system of refrigeration a continuous current of dry, cold air is passed through the food chamber, carrying off all exhalation arising therefrom. Another feature is the crystopal lining, a damp-proof substance not affected by fluctuation of temperature, and nothing will stain or tarnish it.

The Vincit Co., Ltd., 117B, Queen Victoria Street, E.C. Catalogue of Carborondum and "Electrite" Wheels.

Tarmaciser, Ltd., 7, Victoria Street, S.W. Circular describing the company's process and apparatus for treating roads with tar to allay dust.

MANUFACTURERS' NOTES.

The Frictionless Engine Packing Co., Ltd., of Harpurhey, Manchester, have found it necessary to issue the following apology:—

I, R. D. Smith, trading as the North Eastern Packing Co., at West Hartlepool, hereby express my regret to the Frictionless Engine Packing Co., Ltd., of Hendham Vale, Harpurhey, Manchester, who are the registered proprietors of the word 'Karmal,' for having sold steam packing, not of their manufacture, under the name of 'Karmal' packing, and undertake that I will not in future sell any steam packing not of the Frictionless Company's manufacture under any name of which the word 'Karmal' shall form part.

The Yorkshire Machine Tool and Engineering Works will in future be known as the Alma Machine Tool and Engineering Works, Liversedge, (England).

This company, recognising the necessity of specialising on up-to-date lines, and of turning out only high-class tools at moderate prices, have for some time past been bringing their manufacturing equipment up to the recognised modern standard, and have recently availed themselves of the services of Mr. T. H. Webb, M.I.Mech.E., as General Manager. Mr. Webb is well known as an expert in up-to-date machine tool practice, and it may be mentioned that he has resigned an important position in the management of the Birmingham Small Arms Works to take up the appointment at Liversedge.

Pumping Porridge.—Whilst on her homeward voyage from the Black Sea, the SS. *Craigellachie* (of Leith) with a cargo of grain, barley meal, &c., came into collision with an iceberg in the sea of Azov, and started some rivets on the water line in the forepeak. This caused a leakage through the rivet holes, and encountering a gale and heavy seas in the Bay of Biscay, the Captain, instead of proceeding to his port of destination (Hamburg), thought it advisable to put into Plymouth, arriving there about 5 p.m., on Saturday, April 6th. A firm of engineers there (Messrs. Parkyn & Co.) arranged with the Captain to pump out the forepeak, from which several hundred bags of barley meal had been thrown overboard between the Black Sea and Plymouth. The remaining bags having burst the forepeak was full of a thick substance, a mixture of the meal and water. After trying a No. 2 Pulsometer pump, obtained locally, it was decided to wire to the Pulsometer Engineering Co., Ltd., Reading, for a larger size of pump, which was accordingly done, and a No. 4 Pulsometer pump, sent by passenger train, reached the ship at 6.30 p.m., on Monday, April 8th. This pump was fixed in the forepeak of the *Craigellachie*, started pumping at 3 a.m. Tuesday, and continued till 8.30 p.m. the same day, the pump working splendidly and discharging, it was reckoned, about 60 to 80 tons of the "porridge." The ship sailed from Plymouth at 9 p.m. on the Tuesday, and much satisfiaction was expressed by the Superintendent of the Company, and all concerned, at the splendid results obtained and at the expeditious manner in which the work had been executed.

SECOND PRIZE COMPETITION FOR ENGINEERS.

As announced in our last issue, the award for the best and most practical article submitted in connection with the first £10 prize competition for engineers has been made to—

MR. WALTER DUCKITT,
Northfield, Birmingham,

whose contribution on THE RELATIVE VALUE OF MILLING AND PLANING appears in another portion of this issue.

The evident popularity of the scheme, manifested by the number of contributions submitted, has decided us to offer another

PRIZE OF £10

for what is, in the opinion of the Editor, the best article on one of the following subjects, under the conditions given below:—

1. Live Steam Feed Heating.
2. Flame Arc Lamps.
3. The Management of Steam Turbines.

INSTRUCTIONS AND CONDITIONS.

Articles must not contain less than 2,000 words, and must be written on one side of the paper only, and be signed by the competitor.

Drawings and sketches must be on separate sheets of paper.

A short biographical sketch of the competitor's technical experience should accompany the article.

The right is reserved of publishing the prize article, and also any of the others sent in; but in the case of the latter, payment will be made for the same at our usual scale rates.

The Editor's decision in all matters connected with the competition shall be final, and binding on all the competitors.

All articles should be addressed to the Editor of THE ENGINEERING REVIEW, 104, High Holborn, London, W.C., and marked on the outside, "Competition," and the same must be received not later than August 1st.